NONDESTRUCTIVE EVALUATION (NDE) CAPABILITIES DATA BOOK

(Third Edition)

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This Data Book consolidates and organizes available reference data for demonstrated NDE performance capabilities into a single source. Guidelines are presented for selecting options for use of NDE and for assessing the potential to meet design requirements (critical flaw detection requirements). Guidelines for demonstration of specific NDE process capabilities are also presented. Following a 65 page text (7 chapters) describing various aspects of NDE capabilities quantification, probability of detection (POD), and damage tolerance concepts, 423 POD curves are organized and presented in a series of Appendices organized by NDE method. A documentation page precedes each dataset and provides a condensed description of the test object, test artifact and data collection conditions follow the documentation page. POD data are generally presented as a function of crack length. For selected datasets, POD data are also presented as a function of crack depth and crack depth-to-thickness ratio. POD curves are based on hit/miss data using the log-logistic model. Original reference source information is provided for each dataset.

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PREFACE

This Third Edition of the NONDESTRUCTIVE EVALUATION (NDE) CAPABILITIES DATA BOOK was prepared as a Technical Area Task under the auspices of the Nondestructive Testing Information Analysis Center (NTIAC) at Texas Research Institute Austin, Inc. (TRI/Austin) under Contract SPO700-97-D-4003. Funding for the Third Edition was provided by the Federal Aviation Administration (FAA) through the FAA Airworthiness Assurance NDI Validation Center (AANC) at Sandia National Laboratories under Subcontract AU-6825. The First Edition of the NDE CAPABILITIES DATA BOOK, published in May 1996, was prepared as an NTIAC Technical Area Task under Contract DLA900-90-D-0123, Delivery Order No. 0005, with funding provided by the Defense Technical Information Center (DTIC). The Second Edition of the NDE Capabilities Data Book, published in May 1997, was prepared as an NTIAC Technical Area Task under Contract DLA900-90-D-0123, Delivery Order No. 0014, with funding provided by the FAA. Compilation of all three Editions of the Data Book was accomplished jointly by Mr. Ward D. Rummel and Dr. George A. Matzkanin, NTIAC. Data analysis and organization were performed primarily by Mr. Rummel's team under Lockheed Martin and D&W Enterprises, Ltd. subcontracts from TRI/Austin.

The NDE CAPABILITIES DATA BOOK is intended to provide a condensation of available reference data for demonstrated NDE performance capabilities (probability of detection, POD) in a single source. It is expected that the Data Book will be updated as new data are generated and made available; the three-ring binder design provides flexibility for incorporating future additional information in individual chapters and in the form of added appendices. The Third Edition is available in both hard copy printed form, and on compact disk (CD) in Microsoft Windows 95/Word 6.0/ Excel 7.0 formats. Both NDE capabilities (POD) and the raw data used in the analysis are archived in electronic form on the CD.

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This document reflects the contributions of a multitude of personnel and the support provided by sponsoring agencies to advancements in NDE technology. The work and support of the entire NDE community are appreciated and reflected in the results contained herein. In particular, in compiling the First Edition, we would like to recognize the contributions of W. L. Castner and Royce Foreman of the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center; John Knadler and Ken Woodis of the NASA Marshall Space Center; Donald Forney and Thomas Cooper of the Air force Wright Laboratory (now with Universal Technology Corporation); A. Fahr, D. Forsyth, M. Bullock and W. Wallace of the Institute for Aerospace Research, Canada under sponsorship of the AGARD-NATO organization; Alfred Broz and Christopher Smith of the Federal Aviation Administration; and Floyd Spencer of the Sandia National Laboratories. Finally, we recognize and appreciate the work of Donald L. Long, Lockheed Martin, for his work in reducing data acquired during preparation of the First Edition to the common format used in this compilation.

OVERVIEW

The NDE CAPABILITIES DATA BOOK consolidates and organizes available reference data for demonstrated NDE performance capabilities into a single source. In the First Edition, data generated and documented in various forms over the past 25 years through a number of government and private programs were analyzed, organized and presented in a systematic, common format. The Second and Third Editions include more recent NDE performance capability data. Guidelines are presented for selecting options for use of NDE and for assessing the potential to meet design requirements (critical flaw detection requirements). Guidelines for demonstration of specific NDE process capabilities are also presented.

Following a 65 page text (7 chapters) describing various aspects of NDE capabilities quantification, probability of detection (POD), and damage tolerance concepts, 411 POD curves are organized and presented in a series of Appendices (an Index to the Appendices is provided). The Appendices are organized by NDE method to provide reference POD data; NDE procedure capabilities included in the Data Book are:

ET - Eddy Current Inspection
UT - Ultrasonic Inspection
RT - X-Radiographic Inspection
MT - Magnetic Particle Inspection
VT - Visual Inspection
ZT - Emerging Inspection Processes
PT - Liquid Penetrant Inspection (visible and fluorescent)

A documentation page precedes each data-set and provides a condensed description of the test object, test artifacts, NDE procedures and results summary. The POD curves for varying test object, test artifact and data collection conditions follow the documentation page. POD data are presented as a function of crack length, and as a function of crack depth and crack depth-to-thickness ratio for selected data sets. POD curves are based on hit/miss data using the log-logistic model. Original reference source information is provided for each data set.

Materials covered in the **First Edition Data Book** include:

Aluminum (2219 T-87 and 2024 T-37)
Stainless steel (AMS 355)
Titanium-6Al4V

POD curves added in the **Second Edition Data Book** for specific applications include:

4340 Steel Flat Plate Panels
Bolt Holes in J85 Seventh Stage Compressor Disks
Visual Inspection of Fatigue Cracks in Inconel 718 and Haynes 188 Flat Plates
X-Radiography of 0.060 Inch Thick and 0.250 Inch Thick 4340 Steel Flat Plates
"Edge of Light" Inspection of Bolt Holes in J85 Seventh Stage Compressor Disks

POD curves added to the **Third Edition Data Book** for specific applications include:

Aircraft Stiffened Stringer Panels
Lack of Penetration Defects in Aluminum Alloy GTA Welds
Longitudinal and Transverse Fatigue Cracks in Welds with Crowns
Longitudinal and Transverse Fatigue Cracks in Flush Welds
Water Washable Fluorescent Penetrant on Haynes 188 Flat Panels

If you have validated POD data that you would like to contribute to future added appendices/applications of the NDE CAPABILITIES DATA BOOK, please contact:

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1. INTRODUCTION AND SUMMARY

Nondestructive Testing (NDT), Nondestructive Inspection (NDI) and Nondestructive Evaluation (NDE) denote variations in application of materials evaluation technology that range from process control to the measurement of a material characteristic that is critical to the structural integrity and safe operating life of an engineering system. NDE is used in this document to provide identify to the integrated technology of quantitative materials evaluation. A major feature of the technology is that materials evaluation is completed without changing or destroying the object of interest. Familiar processes / procedures that are part of the technology include:

- Liquid penetrant inspection;
- Magnetic particle inspection;
- Radiographic inspection (X-ray and gamma ray);
- Electromagnetic inspection;
- Ultrasonic inspection; and
- Thermographic inspection.

Questions of primary engineering interest in the application of NDE are:

- What inspection methods are applicable?
- How small a flaw can it detect?
- What are the relative costs of inspection?
- What special equipment and/or facilities are required?
- What are the special personnel training and skill development requirements?
- What objective evidence of the inspection (out-put) is provided?
- What are the requirements for demonstrating an NDE procedure performance capability level?
- What are the requirements for process control to maintain a performance capability level?
- What are the human factors requirements for demonstrating and maintaining a performance capability level?
- What objective evidence of NDE procedure / personnel performance capabilities are available?

Numerous references are available to explore the basic principles and functional applications of NDE methods [REF 1-1]. In like manner, reference materials for general personnel qualification are available [REF 1-2]. Data on the performance capabilities of various NDE procedures (How good are the procedures?) are, however, scattered in different reference sources and are not conveniently available to the user community. This ***NONDESTRUCTIVE EVALUATION (NDE) CAPABILITIES DATA BOOK*** is intended to be a baseline for engineering analyses in the form of a condensed reference to previously demonstrated NDE capabilities. It is intended to be a companion to

DAMAGE TOLERANCE and **SAFE-LIFE** analysis tools that are integral to quantitative design practices and "fracture control" and **SAFE-LIFE** of engineering hardware. The starting point for **DAMAGE TOLERANCE** and **SAFE-LIFE** analyses is input of a flaw size that is assumed to be present at the time of hardware / system acceptance test or at the time of inspection during periodic maintenance / overhaul. **DAMAGE TOLERANCE** and **SAFE-LIFE** analyses provide a quantified basis for structural integrity in the form of a "critical crack size" or "assumed crack size" required for **SAFE-LIFE**. The most desirable assumption would be **"no cracks"** and many engineering documents specify **"no cracks"** as a requirement for acceptance. However, experience, economics and materials behavior do not, however, support a **"no cracks"** criteria as a basis for **SAFE-LIFE** design.

The evolution of deterministic engineering design processes often included destructive and nondestructive materials evaluation to provide confidence in the "fitness for purpose" of hardware that was identical, or similar to, hardware that had been in service in a particular application and / or industry. If a component failed, subsequent components of similar design would have added requirements that often included a requirement for nondestructive inspection / materials evaluation. A **SAFE-LIFE** was achieved, in part, by reliance on the unquantified capabilities of a specified nondestructive inspection procedure. A specified **"no cracks"** criteria was, therefore, that crack size that was revealed by application of the specified nondestructive inspection / evaluation (NDE) procedure.

Experience has shown a wide variation in the "crack detection" capabilities for NDE procedures that are completed to the same "specification" requirements. Failure of a procedure to meet expectations is most often due to a failure to qualify and validate procedure performance or to a degradation of a procedure with time. The result of application of an inadequate or degraded procedure may result in considerable (and often unanticipated) risk to the safe-life of an engineering system. "Standardization" of NDE procedures has been addressed by the generation and application of "NDE specifications". Such specifications have most often addressed the "HOW TO" element of procedure application with lesser emphasis on quantification of results / output or on the process control required to attain NDE process, and hence, hardware reliability.

A firm requirement to quantify and demonstrate the capabilities of NDE procedures was imposed by the development and application of fracture mechanics in **DAMAGE TOLERANCE** and **SAFE-LIFE** design practices. Fracture mechanics analysis produced a single valued **"critical crack size"** as a basis for **DAMAGE TOLERANCE** and **SAFE-LIFE** analysis. Detection of cracks below the **"critical crack size"** is required for the implementation of **"fracture critical"** and **SAFE-LIFE** analysis. Nondestructive evaluation involves multiple process variables and does not produce a single valued result. Variances in nondestructive evaluation process capabilities were addressed using the tools that were developed for establishing materials properties design values in the form of the **"Probability of Detection (POD)"** as a function of crack / flaw size.

The concept of **"Probability of Detection (POD)"** was introduced in 1973 and was incorporated into design requirements for the National Aeronautics and Space Administration's (NASA), Space Shuttle program. [REF 1-3 thru 1-6]. Similar requirements were initiated by the United States Air Force [REF 1-7 thru 1-9]. The **"Probability of Detection (POD)"** concept and methodology have gained widespread acceptance and continuing improvements have enhanced its acceptance as a useful metric for quantifying and assessing NDE capabilities. Since a wide range of NDE methods and procedures are used in "fracture control" of engineering hardware and systems, a large volume of POD data has been generated to validate the capabilities of specific NDE procedures in a multitude of applications.

It is beneficial to the technical community, and to the general public, to share engineering data and to provide common baselines for assessing the capabilities and for quantifying the confidence measurements that are integral to modern engineering technology products. Such engineering data have been most often consolidated and documented in the form of "Handbooks of Design Principles, Values and Parameters" that are shared by engineers who work in a specific technology discipline. The "Handbook" values and data are incorporated into "state of the art" engineering practices to produce a "standard" for continuing engineering application, and are incorporated into education programs for the next generation of engineers.

POD data are specific to specific NDE procedures and applications and do not readily fit the "Handbook" paradigm. Condensation of POD data are therefore presented in the form of this "Databook" and users are cautioned that the data are valuable for purposes of reference and general understanding of NDE capabilities, **but specific NDE capabilities validation data and disciplines must be generated by the user to support critical hardware design and use.**

In summary, the purpose of this databook is to provide a condensation of quantified capabilities data that have been developed and documented in previous applications. Its intended use is as a single point reference to results that have been obtained in state-of-the-art NDE applications and thereby provide a link to prior art. The modular format of the data book anticipates data additions that may include additional NDE processes and procedures and various procedure applications.

Guidelines are presented for selecting options for use of NDE and for assessing the potential to meet design requirements (critical flaw detection requirements). Guidelines for demonstration of specific NDE process capabilities are also presented. The complex, multiparameter nature of NDE procedure application demands characterization and demonstration of specific user procedures to provide confidence in performance in a specific application. The data presented herein may be used as a baseline for prediction and comparison of general capabilities and to increase confidence in the use of limited

data sets that are consistent with those obtained in prior work. The link of user data to *NDE CAPABILITIES DATA BOOK* data is the responsibility of the user.

NOTE: Nondestructive evaluation capabilities vary widely with characteristics of the test object and with precision in NDE procedure application. The guidelines and data presented are specific to the applications and application conditions that accompany the data. Special conditions and/or stage of application of NDE in the production process must be included in the NDE requirements and process analyses. For example, etching may be required before penetrant inspection; inspection may be required before shot peening; inspection may be required before and after proof loading; special considerations for mal-oriented flaws may be required; and special considerations for special materials, processes or applications may be required.

This document shall not be used as the primary basis for establishing acceptance criteria. Design acceptance criteria must be established analytically as part of the integrated design process (i.e. system functional analyses, stress analysis, thermal analysis, fracture mechanics analysis, use constraints, life-cycle fatigue analysis [(SAFE-LIFE), (FAIL SAFE), (DAMAGE TOLERANCE)] etc.)

CAUTION: **No direct or indirect involvement or responsibility is taken for interpretation or use of data presented herein. "Qualification, Validation and Certification" of procedures or individual capabilities by a user and liability resulting from performance of inspections by the user are the responsibility of the user / performing organization. No real or implied liability is assumed by reference to data presented herein.**

REFERENCES:

1. "Nondestructive Testing Handbook" Series, American Society for Nondestructive Testing, Columbus, Ohio.
2. "Recommended Practice No. SNT-TC-1A", American Society for Nondestructive Testing, Columbus, Ohio, 1984 Edition.
3. Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, The Detection of Fatigue Cracks by Nondestructive Testing Methods, NASA CR-2369 February 1974.
4. NHB 8071.1, Fracture Control Requirements for Payloads Using the National Space Transportation System (NSTS), National Aeronautics and Space Administration.
5. NASA SP-8095, Fracture Control of Space Shuttle Structures, National Aeronautics and Space Administration.
6. NASA SP-8040, Fracture Control of Metallic Pressure Vessels, National Aeronautics and Space Administration.
7. MIL-STD-1530, Aircraft Design Requirements
8. MIL-A-83444, Damage Tolerance Requirements
9. MIL-I-6870 Inspection Requirements

2. ABOUT THE DATABOOK

2.0 PURPOSE

The purpose and goal of the *NDE CAPABILITIES DATA BOOK* are to document demonstrated capabilities of NDE procedures in various applications and to identify NDE process parameters, controls and variances that characterize the results obtained. Collection, condensation and quantification of process capabilities are hallmarks of a maturing engineering technology. The science of NDE and NDE applications are expanding at a rapid rate and will increase further as economies drive life-extension of engineering systems as a tangible alternative to replacement. Expectations for engineering systems will remain high and accountability in systems management will drive accountability in NDE and maintenance procedures.

Documented NDE performance capabilities are necessarily incomplete and are intended to be updated as new data are generated and made available. The data book is therefore partitioned such that any chapter may be individually updated. Additions to the data book may be made in the form of added appendices. An important aspect of the data book is the archiving of "raw data" such that users may compare documented performance capabilities for a specific procedure with prior, demonstrated capabilities. Raw data are archived in both hard copy and electronic form (EXCEL spreadsheet [REF 2-1]) and may be provided under separate cover for user convenience. The raw data are also expected to provide a baseline for the development of first principles science methods and thereby to aid in the advancement of NDE technology.

Data presented are intended to be used for purposes of reference only. The complex nature of NDE processes and applications require that individual capabilities demonstrations be completed to meet the requirements of a specific design / application.

2.1 ANTICIPATED USERS

Anticipated individual users of the information / data provided are:

REQUIREMENTS

- The designer
- The materials engineer
- The reliability and safety engineer
- The maintenance engineer
- The manufacturing / production process engineer
- The liaison (rework and repair) engineer
- The life-cycle maintenance manager
- The hardware / system operator and customer(s)

NDE PROCESS DESIGN

- The NDE engineer

PROCESS IMPLEMENTATION — • The NDE process manager

RESEARCH / ADVANCED NDE TECHNOLOGY — • The NDE technology engineer / scientist

The engineering design process involves the integration of fit, form and function requirements with weight, producibility, durability and margins for critical parameters. The design envelope is necessarily constrained by producibility and durability / maintainability and trade-offs are often required to optimize the life-cycle function of the design object. The role of NDE is that of providing confidence that indirectly measurable materials properties and materials continuity requirements have been satisfied Damage tolerance and safe-life design processes require quantification of NDE capabilities for use as a design parameter. It is important to note that most design applications require only confirmation that materials / use parameters are within the design envelope established by "prior-art" design / use and only a small number of designs impose special NDE requirements for "fracture control". The transition from a **"No flaws / cracks"** to an **"assumed initial flaw / crack size"** as a basis for damage tolerance and safe-life design challenged both the design and NDE communities.

Communication of design requirements and NDE performance requirements as quantitative values is an iterative process and requires integration of an expanded group of technologists into the design process. The initial question from the designer is:

> **"How SMALL a flaw can be found by NDE?"**

The proper question is:

> **"How LARGE a flaw might be missed by NDE?"**

The answer to the second question is dependent on a multitude of parameters that include: part material, part configuration, part accessibility, surface condition, sequence in the part life-cycle, etc. As the design process progresses, essential characteristics of the design must be communicated and quantified to provide the NDE crack size metric. Traditional engineering practices have relied heavily on "prior art" as the starting point for a new design and damage tolerance and safe-life design is no exception. Since much of the "prior art" in NDE did not involve quantification of capabilities, some assumptions were required to translate "prior art" to "generic NDE capabilities". "Generic NDE capabilities" were incorporated into "Fracture Analysis Models" [REF 2-2] and have been up-dated as more quantitative data were obtained. The "generic NDE capabilities" assume knowledgeable and disciplined NDE application / process control and are <u>not</u>

"recipes" for success by ceremonial applications of NDE processes. For critical designs / applications, specific NDE procedures must be developed and validated to assure that the quantified design assumptions / requirements are met. "Special NDE" disciplines must then be ap lied to assure continuing performance of the validated capability.

A starting point for both "generic NDE capabilities" and for "special capabilities" requirements is "prior art" that has been demonstrated in similar applications. This data book provides a reference source for "prior art" demonstrations. Consider the functional diagram shown in Figure 2-1.

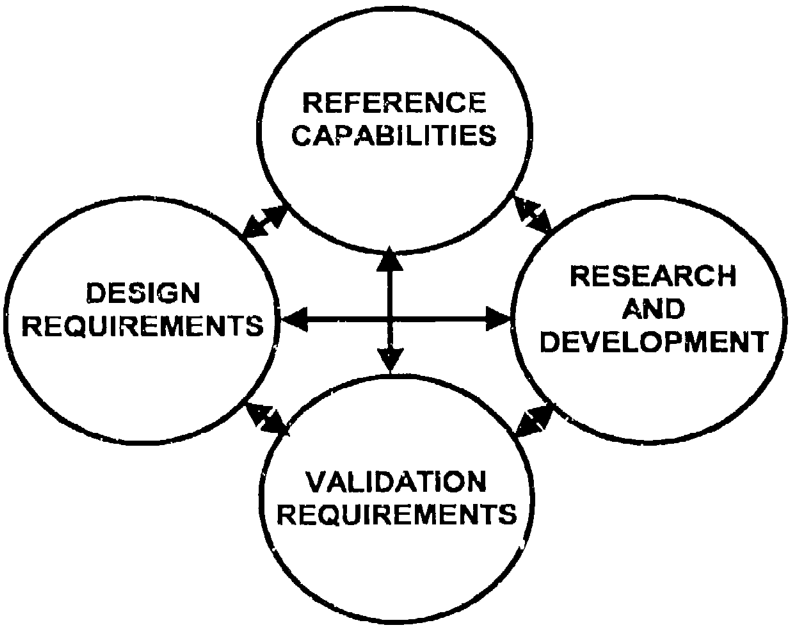


FIGURE 2-1 NDE Integration in the Design Process

Both the design engineer and the NDE engineer have an initial common baseline in reference to "generic" and demonstrated NDE capabilities. If the design / use requirements are outside the envelope of "prior art" or the design is determined to be "fracture critical", special NDE requirements must be applied. NDE engineering involvement for both "generic" and "special NDE" is required early in the design process to assure that the necessary NDE tools / processes are available for implementation. If the NDE requirements are beyond the "prior art" knowledge / database, research and development may be necessary to implement the design. Cost and schedule considerations imposed by "special NDE" must be included in the design implementation process. The next critical NDE task in design implementation is in validation of NDE procedures to be applied to assure that design requirements are met. The validation step is critical to all NDE applications and is not limited to the implementation of special NDE requirements. Provisions must be made for re-validation to accommodate NDE

procedure / equipment / personnel changes and for validation of procedures used in "rework" / design modification / changes.

The needs of all users have been considered in the organization of the data book text. The needs of the NDE engineer have been given primary consideration in the organization of the NDE capabilities data.

In NDE applications, the persistent and incorrect perceptions of engineers, scientists, and the general public are that:

- **All inspections provide 100% coverage;**
- **No flaws are present after an inspection is completed; and**
- **The inspection process sets the acceptance criteria.**

This data book provides an additional reference to both state of the art engineering processes and realistic expectations of the processes.

2.2 DATA ORGANIZATION FOR THE NDE USER

The nature and capabilities of NDE procedures in various applications are complex and are dependent on the:

- Nature of the test object
- Nature of the flaw (characteristic to be detected / quantified)
- NDE application environment
- NDE processing materials
- NDE equipment
- Reference artifacts used in "calibration" / "process control"
- The procedure used in establishing the reference measurement (calibration level)
- NDE process / procedure and method of application
- NDE skills / human factors

The complex, multiparametric nature of NDE procedure application demands characterization and demonstration of specific user procedures to provide confidence in performance in a specific application. The demonstrated NDE data are organized for convenient reference to "prior art" and may not be representative of the capabilities of a specific application using different parameters and / or personnel skill capabilities. The responsibility remains with the user to provide validation of individual NDE capabilities.

NOTE: This document shall not be used as the primary basis for establishing acceptance criteria. Design acceptance criteria must be established analytically as part of the integrated design process (i.e. system functional analyses, stress analysis,

thermal analysis, fracture mechanics analysis, use constraints, life-cycle fatigue analysis [(SAFE-LIFE), (FAIL SAFE), (DAMAGE TOLERANCE)], etc.)

2.3 NDE PROCESSES ADDRESSED

Nondestructive evaluation (NDE) procedures using various physical / process principles are used in various applications. NDE procedure capabilities included in this document are:

- **ET** - Eddy Current inspection
- **MT** - Magnetic Particle Inspection
- **PT** - Liquid Penetrant Inspection (visible and fluorescent)
- **UT** - Ultrasonic Inspection
- **VT** - Visual Inspection
- **RT** - X-radiographic Inspection
- **ZT** - Emerging Inspection Processes

Additional classifications may be added as additional NDE methods are more generally applied.

Note: Trademark terms commonly used in reference to widely applied NDE/NDI processes include: "Zyglo" = Fluorescent penetrant inspection; "Dye Chek" = Visible penetrant inspection; and "Magnaflux" = magnetic particle inspection ("Zyglo", "Dye Chek" and "Magnaflux" are Trademarks of the Magnaflux Corporation, Chicago, Ill. and no endorsement is offered or supported).

2.4 SUMMARY

This *NDE CAPABILITIES DATA BOOK* is viewed as a companion to damage tolerance and safe-life analyses tools and handbooks. Requirements, roles and responsibilities for the application, quantification and use of general practice and specific (special NDE) practice data are identified. Links to and acceptability of design requirements are described and methods for using the documented capabilities are discussed. The *NDE CAPABILITIES DATA BOOK* is offered as a baseline reference source for quantitative NDE procedure application. The user is responsible for excellence in application and in use of the data presented.

REFERENCES:

1. "EXCEL 5.0", Microsoft Corporation, Redmond, WA.
2. Fatigue Crack Growth Computer Program "NASA/FLAGRO", Version 2.03, National Aeronautics and Space Administration, JSC-22267A

3. NONDESTRUCTIVE EVALUATION (NDE) APPLICATIONS

3.0 NDE USAGE

Nondestructive evaluation is used for many purposes and the required rigor of application may vary with intended use of the results. Use of NDE process output includes:

- General industrial process control;
- General exchange in commerce;
- General configuration and general fitness for purpose acceptance;
- Continuing fitness for purpose acceptance in maintenance;
- Fitness for purpose acceptance during and following rework and repairs;
- Fitness for purpose assessments for life extension

The known characteristics, capabilities and rigor in application vary with the specific needs and heritage of the application. For process control and general applications in commerce, emphasis is on continuation of the processes / procedures that made the product successful. For new applications and/or required improvements in application, use of emerging engineering tools may provide an economical alternative. It is important to note that:

⇨⇨All NDE process applications do not require specific quantification⇦⇦

NDE procedures incorporate multiple parameter processes and systematic control of process parameter variations are required to assure continuity and consistency in application. If large margins for variance are accommodated in applications requirements, the historical, deterministic approach to process control may be adequate to meet requirements. When a quantified approach is required, the methods and engineering database provided herein may be more applicable

3.1 NON-QUANTITATIVE NDE APPLICATIONS AND TECHNOLOGY GROWTH

Quantification of NDE capabilities is a relatively new element of NDE engineering technology and many applications do not require quantification or qualification of NDE process capabilities. These include non-critical applications, applications with large design margins, use of NDE sensors in automated condition sensing / in-process control, (usually very large margins), and applications that involve extension of "prior art". In general, if the result of failure of a component does not involve loss of life or significant (life-cycle system) economic loss, NDE capabilities may not require demonstration and may be assumed to be at a "state of the art" level. Excellence in meeting requirements in such applications is considered to be a part of overall product "workmanship".

3.1.1 NDE IN GENERAL COMMERCE

NDE processes applied in general commerce are used to provide control in assuring the "general quality" of the product being provided. Many of the "codes, standards, specifications and regulations" used in general commerce impose requirements to perform NDE (type) and procedural (how to) requirements for applying the NDE process, but have no requirements for quantifying the level of discrimination provided by the process. The "calibration" (reference artifact(s)) procedure is assumed to provide a reproducible (but unquantified) level of discrimination and the discrimination level is often "assumed" to be at the "calibration" level. For example, eddy current inspection may be applied to the acceptance of welded pipe for use in pressurized systems. Pipe produced that does not meet the "general quality" for use in pressurized systems may be used as fence posts. "prior art" provides the basis for use of the "specified" procedures and the acceptance margins (design margins) that have been demonstrated (but not quantified), in practice, to provide a "safe-life" for the intended purpose (fitness for purpose and life-cycle service usage). Service use as fence posts differs greatly from that in a pressurized pipe systems and the "fitness for purpose" requirements vary with the "general quality level" implied by application of the NDE procedure.

"Prior art" is the basis for many of the NDE procedures applied in commerce and has provided a basis for acceptance of the general NDE capabilities performance levels that are used in general NDE engineering. The responsibility for maintaining a continuing level of NDE process control is part of the warranty of the producer and a part of the warranty of the user / operator. Quantification of NDE procedure capabilities as described herein, provides an objective basis for assuring a continuing level of NDE process control and may be linked to "prior art" applications to provide continuity in product / process reproducibility.

3.1.2 NDE IN GENERAL INDUSTRIAL PROCESS CONTROL

NDE is routinely applied in general industrial process control for both feedback and acceptance. Acceptance requirements are general and most often provide the evidence and confidence level in process "workmanship" and "product excellence". A familiar example is the application of X-radiography and liquid penetrant processes to monitor the general quality and integrity of welds. The intended use of the welds may not be specified or reflected in the "acceptance criteria", but instead establishes a reasonable level of "workmanship" for the weld process. Associated with the acceptance are "assumed" levels of capabilities and excellence in the X-radiographic and liquid penetrant (NDE) processes being applied. Quantification of NDE procedure capabilities as described herein, provide tools for establishing an objective basis for assuring a continuing level of NDE process control and the assumed level of quality of the weld processes being applied.

3.1.3 USE OF "PRIOR ART"

NDE procedure capabilities have been assumed in most "prior art" and/or were derived empirically from failures that occurred when NDE margins and boundaries were established by trial and error. Quantification of NDE procedure capabilities as described herein, provides an objective, low risk basis for assuring a continuing level of NDE process discrimination and may reduce the need for a qualification / destructive test article. Quantification provides a link to general engineering and science based applications of NDE technology.

3.2 APPLICATIONS TO DAMAGE TOLERANT / SAFE-LIFE IN ASSURING STRUCTURAL INTEGRITY IN DESIGN AND USE

Advancements in design / analysis practices include requirements for quantification of NDE capabilities and for specific quantification of acceptance requirements (criteria). Advanced analyses incorporate material fracture and fatigue properties in service usage to envelope design parameters and life-cycle requirements into safe-life system design / management. The obvious economic advantages of moving from more deterministic to more quantified design / analysis approaches are in shorter development cycles, efficiencies in quality control, improved design efficiencies (fitness for purpose), durability in design / use, and improvements in confidence levels for engineering structures / system performance. The disadvantages of this change are in both changes in engineering practices and in the availability of data to support the new approaches.

Key factors in damage tolerant / safe-life analyses are the assumption of an initial flaw size, and that supporting NDE technology can support that assumption. The "assumed" initial flaw size has been and will continue to be based on both deterministic, heritage approaches and on data provided by characterized and quantified NDE procedures analysis. The NDE approach is increasingly the preferred method applied to in-service "fitness for purpose" analyses, life-cycle management analyses, and life-extension analyses. Requirements for analyses using quantified NDE approaches are discussed in detail in Section 4 of this databook and are the primary basis for quantifying and documenting NDE capabilities in this data book.

3.3 COMMON NDE CAPABILITIES ASSUMPTIONS AND MYTHS

The evolution of NDE technology was traditionally deterministic and was most often implemented to address a specific failure mode for a process, structure or system. The "last resort/necessary evil" approach to NDE application for "failure prevention" resulted in the origination and propagation of many "claims, myths and unsubstantiated assumptions" of NDE capabilities and the capabilities of specific NDE procedures in

various applications. Although often painful, maturation of a technology necessarily involves organization and quantification of the objective knowledge / data available.

Common myths and misunderstandings in NDE applications include the following:

- **"NO FLAWS CRITERIA"** - NDE is not absolute and "flaws" that are below the detection capabilities threshold may be present after application and discrimination by an NDE procedure;
- **"ASSUMPTION THAT THE NDE CAPABILITY IS AT THE SMALLEST FLAW DETECTED"** - The significant characteristic output of an NDE process in not the "Smallest flaw detected" but the "Largest flaw missed";
- **"ASSUMPTION THAT THE DETECTION AND DISCRIMINATION CAPABILITY OF AN NDE PROCEDURE IS AT THE 'CALIBRATION LEVEL'"** - The discrimination capability of an NDE procedure is rarely at the "calibration" / reference artifact used in set-up of the NDE procedure. Increase of the amplifier gain does not change the discrimination level, but may increase the "noise" response and thereby increase the "false call" level;
- **"CRACKS AND SLOTS ARE EQUAL"** - NDE responses from artifacts such as slots, saw cuts and electrodischarge machined (EDM) notches are rarely the same as the responses from cracks of an equivalent size;
- **"ALL CRACKS ARE CREATED EQUAL"** - Cracks of the same size that are initiated and grown under various conditions may produce wide variation in their respective NDE responses;
- **"CRACKS ARE EQUALLY DETECTABLE UNDER ALL CONDITIONS (LABORATORY / FACTORY / FIELD)"** - Crack response may vary with equipment and application conditions. Attention to "calibration, scanning and personnel qualification" are required to support quantitative field operations.
- **"CRITICAL CRACK SIZE APPLICABLE EVERYWHERE"** - Specification of a critical crack size in general requires information of zoning and expected location of an "assumed crack". The NDE process qualification and application cost will be adjusted to meet specific requirements. Specification of a critical flaw size in one location will not generally be applicable to all locations and flaw orientations.
- **"ALL NDE PERSONNEL PERFORM AT THE SAME LEVEL"** - Personnel training, qualification, and certification ensure performance at the highest possible capability for a specific NDE procedure. Variations in personnel skill and dexterity will produce variations in a specific NDE procedure performance level.

3.4 QUANTIFIED NDE CAPABILITIES

The complex, multiparameter characteristics of NDE procedures present complex characterization requirements. Rigorous NDE procedure application requires specific characterization under the applied operating conditions, by the operators who will be applying the procedure. Full characterization is not required if an inspection procedure

(and/or) operator can be shown to perform at a level that was previously demonstrated for that procedure. This databook is a compilation of the capabilities of procedures that have been demonstrated in various applications and application conditions. Users may demonstrate similarity of procedures and applications as a basis for design, process and/or personnel performance reference.

NOTE: Information and data presented in this Data Book are intended for technical reference only. The responsibility for demonstrating specific NDE capabilities remains with the user.

3.5 SUMMARY

The broad use of NDE in various applications imposes a variety of requirements on NDE process optimization, process control and capabilities. All NDE process applications do not require quantification. An adequate NDE procedure capability is assumed and supported in many "prior art" applications based on "trial and error" in providing the required discrimination. Such procedures are, however, difficult to extend to new applications and/or to meet new requirements. Quantification of NDE procedures capabilities provides a transferable link to new applications and a method of predicting a capabilities margin without a hardware qualification test.

Quantitative design / analyses tools offer economies in design and life-extension at increased confidence levels over "prior art" methods. Quantitative design requirements include requirements for characterization and quantification of supporting NDE procedures and tools. The basis for and examples of such quantification are included in the specific cases analyses in the Appendices of this data book.

4. REQUIREMENTS FOR QUANTIFICATION OF NDE

4.0 DAMAGE TOLERANT / FAIL SAFE / SAFE LIFE ANALYSES

Advanced materials and structures analysis methods incorporate quantification of fracture and fatigue life properties based on knowledge of material / component configuration and condition (integrity). An essential element of both fracture and safe life analyses is the assumption of the presence of an initial flaw, of a known size at the beginning of the material / component life. The analysis methods are collectively known and documented as DAMAGE TOLERANT/ FAIL SAFE analyses [REF 4-1] and SAFE-LIFE analyses [REF 4-2]. These methodologies were developed and were first applied, on a general scale, in the design and life-system management of the National Aeronautics and Space Administration (NASA) Space Shuttle and on the United States Air Force B1 Bomber program. Subsequent designs, life-cycle analyses and life-extension analyses of modern engineering structures and systems have incorporated variations of these methodologies.

A key element of safe-life analyses is the assumption of the presence of an initial flaw. Nondestructive evaluation is the primary tool in both assessing the condition of a safe-life component and in quantifying the flaw size that must be used in the analyses. Nondestructive evaluation is increasingly important in life-cycle management of engineering materials, components, structures and systems. NDE procedure performance based on "best effort" and/or "adequate effort" cannot be expected to support quantified, safe-life requirements. Requirements for quantification of NDE performance capabilities impose changes in design engineering practices, disciplines and documentation (including configuration control) requirements. A "no flaws" criteria is no longer acceptable for either design analyses or for NDE applications that support the safe-life of an engineering system.

4.1 "FRACTURE CRITICAL" REQUIREMENTS

Safe-life analyses provide tools for evolving and quantifying design parameters (constraints and adequacy) and in the identification of life-limiting components. Life limiting components may be designated as "fracture critical" and thereby invoke specific requirements for production, handling, service life usage, maintenance / inspection, inspection intervals, and criteria for "retirement for cause". A "fracture critical" designation is imposed when fracture or failure of the part resulting from the occurrence and/or propagation of a crack may result in a catastrophic event that could result in the loss of life and/or mission. A "fracture critical" designation maybe be imposed by one or more of the following:

- BY DEFINITION - When "prior art" / experience has identified a need for special consideration in design and service usage (for example, a pressure vessel);
- REDUNDANCY / FAIL-SAFE - When the component constitutes a single point failure and safe-life is not within the design margins established by "prior art";

- SAFE-LIFE - When the safe-life analysis / use of the component is not within the established design parameters and margins. The design parameters may include requirements for detection of cracks of a size that is below the accepted limit as designated in "NASA/FLAGRO" [REF 2-2] or other applicable references.

When a component is designated as "fracture critical" analysis must be completed to identify the constraints and requirements for production, acceptance (fitness for service) and use (life limiting / retirement for cause and maintenance (inspection and test) requirements). Key elements in fracture control and life-cycle management are quality control in production and use and nondestructive inspection / evaluation in "fitness for purpose acceptance".. Nondestructive evaluation / acceptance is critical in identifying and quantifying the "initial flaw size" that is used as the starting point for "fracture critical / safe life" analyses and in identifying and quantifying the "detectable flaw size" for incremental "fitness for purpose" inspections.

4.2 NDE CAPABILITIES QUANTIFICATION AND PROBABILITY OF DETECTION (POD)

Two approaches to the incorporation of NDE requirements into design evolved; (1) Characterization of NDE procedures in the form of a "Probability of Detection (POD)" and (2) Deterministic compliance to the requirement by demonstration of capabilities at a fixed (assumed) flaw size (point estimate of detection capabilities). Both methods have value in practical applications, but considerable work in NDE procedure characterization by the POD method was necessary to gain knowledge and data on realistic performance capabilities (putting aside past assumptions and myths); and in providing a basis for confidence in demonstrating compliance in a specific application. The first known report of NDE procedure characterization by the POD method was in work performed under a NASA program to support the design / life-cycle analysis for the NASA Space Shuttle program [REF 4-3]. This work and subsequent assessments using the same methodologies provided the basis for the NASA Space Shuttle design. This work provided the initial basis for the NDE capabilities data that is incorporated in the "NASA/FLAGRO" analysis program [REF 4-2]. An example of a typical "probability of detection (POD)" curve is shown in Figure 4-1.

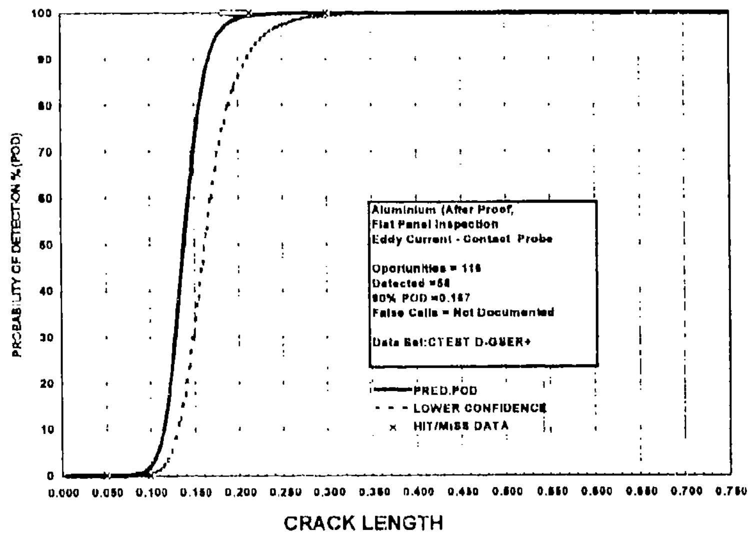


FIGURE 4-1 A Typical Probability of Detection Curve

4.3 "NASA/FLAGRO" INITIAL FLAW SIZES

The "NASA/FLAGRO" program includes "NDE Inspection Technique and Respective Flaw Size Criterion" as default values for various crack cases. The designer has the option of using the default values for initial assessments or to input more specific values based on demonstrated NDE procedures capabilities and supporting data available for the specific design case. The "NASA/FLAGRO" initial flaw sizes take into account some variations in the analysis method, the aspect ratio of the crack and the thickness of the test object. The "NASA/FLAGRO" VERSION 2.03, Tables and reference analysis cases are reproduced (by permission) herein, for user convenience and continuity in reference.

CAUTION: The user is responsible for reference to changes and updates in the "NASA/FLAGRO" program and for use of specific, demonstrated flaw sizes in specific applications.

For purposes of orientation, crack depth, a , is denoted as the crack depth in the thickness or diametrical direction. Crack length, c, is denoted as crack length or half-crack length in the width or peripheral direction. Part thickness is denoted as, **t**, as shown in Figure 4-2.

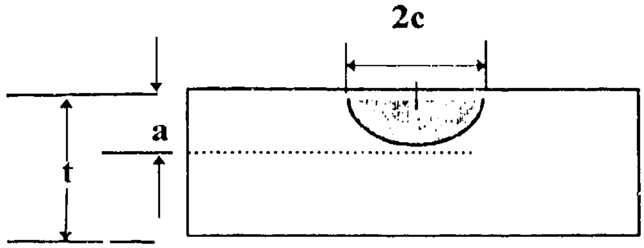


FIGURE 4-2 Cross section view of a part containing a surface (thumb-nail) crack

In the reference case (Figures 4-3 through 4-26) the following notation is used:

a............................Crack depth in thickness or diametrical direction

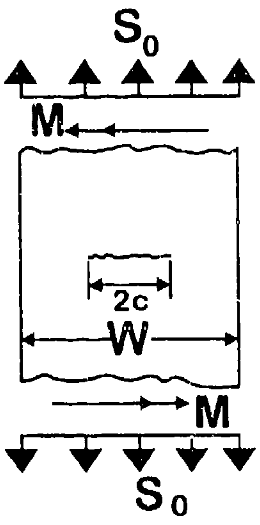
B............................Edge distance for a hole
c............................Crack length or half-crack length in the width or peripheral direction
D............................Hole diameter
M............................Resultant moment
P............................Resultant force
R............................Component radius
S_0, S_1. S_2, S_3, S_4.....Nominally applied stress
α............................Included angle
t............................Thickness of plate, sheet, extrusion, forging
W............................Specimen width

Part geometry, crack location, crack orientation and part load directions are shown for the standard case analyses available within "NASA/FLAGRO" (Table 4-1). The corresponding allowable flaw sizes for various "STANDARD NDE" procedures are shown in tabular form for various case analyses and part thicknesses (Table 4-2).

Table 4-1 - Description of Crack Cases [REF 4-2]

Through Cracks:	
TC01:	Through crack at center of plate
TC02:	Through crack at edge of plate
TC03:	Through crack from an offset hole in a plate
TC04:	Through crack from hole in a lug
TC05:	Through crack from hole in plate with a row of holes
TC06:	Through crack in a sphere
TC07:	Through crack in a cylinder (longitudinal direction)
TC08:	Through crack in a cylinder (circumferential direction)
TC09:	Through crack from hole in a plate under combined loading
TC10:	Through crack from hole in a cylinder (circumferential direction)
Embedded Cracks::	
EC01:	Embedded crack in a Plate
Corner Cracks:	
CC01:	Corner crack in a rectangular plate
CC02:	Corner crack from hole in a plate
CC03:	Corner crack from hole in a lug
Surface Cracks:	
SC01:	Surface crack in a rectangular plate - tension and/or bending
SC02:	Surface crack in a rectangular plate - nonlinear stress
SC03:	Surface crack in a spherical pressure vessel
SC04:	Longitudinal surface crack in a hollow cylinder - nonlinear stress
SC05:	Thumbnail crack in a hollow cylinder
SC06:	Circumferential crack in a hollow cylinder - nonlinear stress
SC07:	Thumbnail crack in a solid cylinder
SC08:	Thumbnail crack in a threaded, solid cylinder
SC09:	Circumferential crack at thread root in a cylinder
SC10	Circumferential crack in a threaded pipe - nonlinear stress

TC01

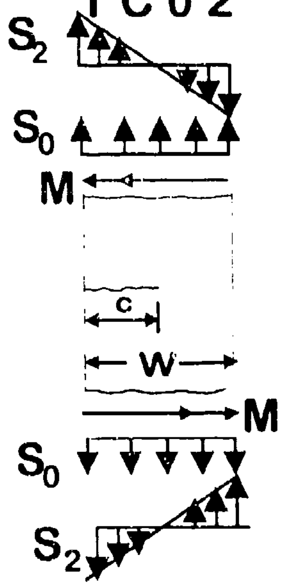


$$S_1 = \frac{6M}{Wt^2}$$

t = thickness

Through Crack at Center of Plate

TC02



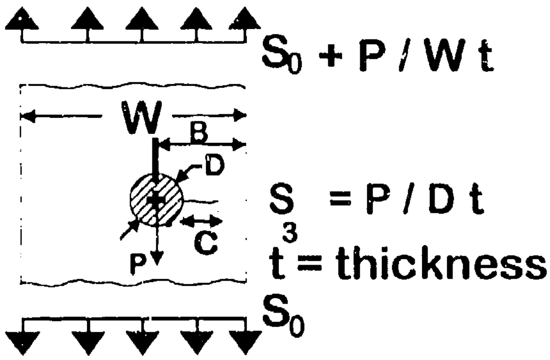
Through Crack at Edge of Plate

Through crack cases 1 & 2

Cross sectional view

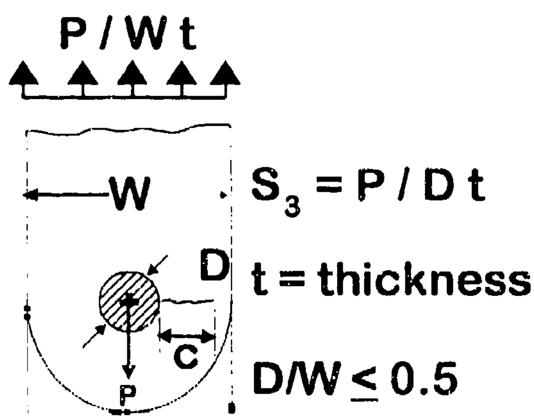
Figures 4-3 (TC01) and 4-4 (TC02) [REF 4-2, Fig. 9]

TC03



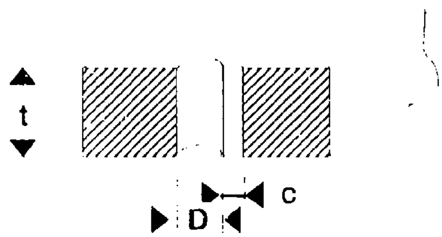
ThroughCrack from an
Offset Hole in
a plate

TC04



ThroughCrack from a
Hole in a Lug

Through crack cases 3 & 4



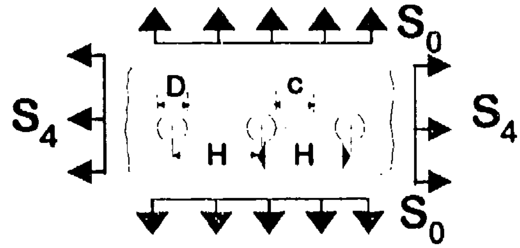
Cross sectional view

Figures 4-5 (TC03) and 4-6 (TC02))
[REF 4-2, Fig. 10]

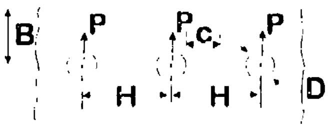
TC05

TC06

TENSION LOADING

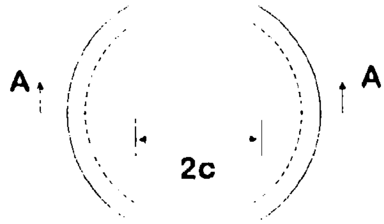


PIN LOADING

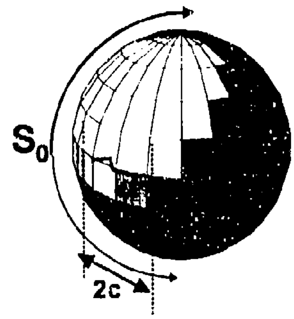


$S_3 = P / D\,t$
t = thickness

ThroughCrack from a Hole in a Plate with a Row of Holes

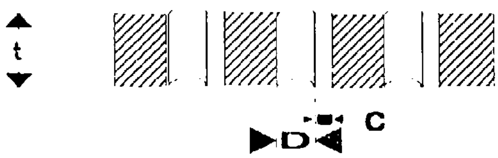


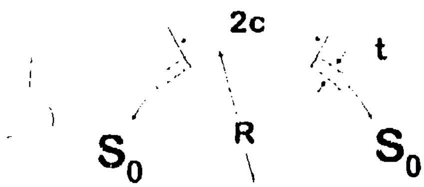
$c / \sqrt{Rt} < 3$



ThroughCrack in a Sphere

Through crack cases 5 & 6

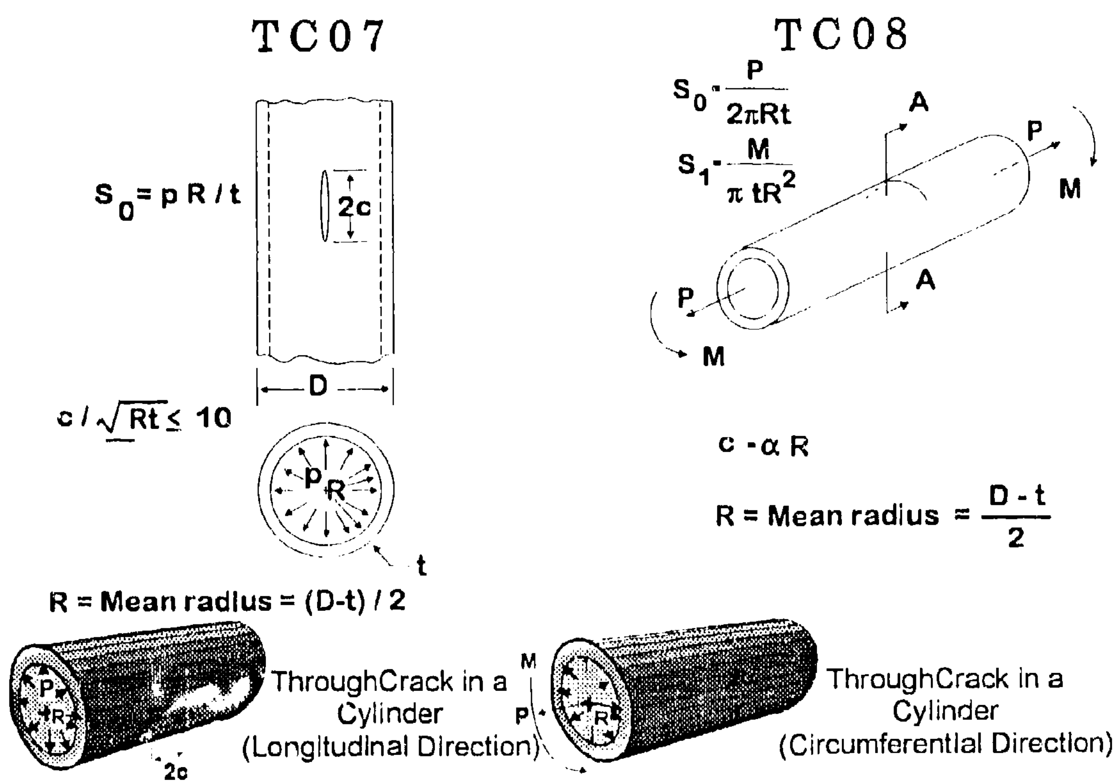




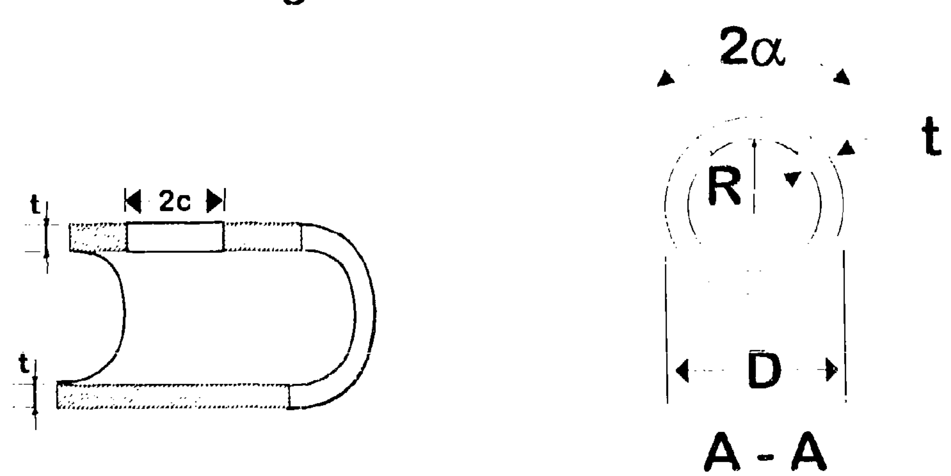
section of sphere AA
R = Mean radius = (D-t) / 2

Cross sectional view

Figures 4-7 (TC05) and 4-8 (TC06))
[REF 4-2, Fig. 11]



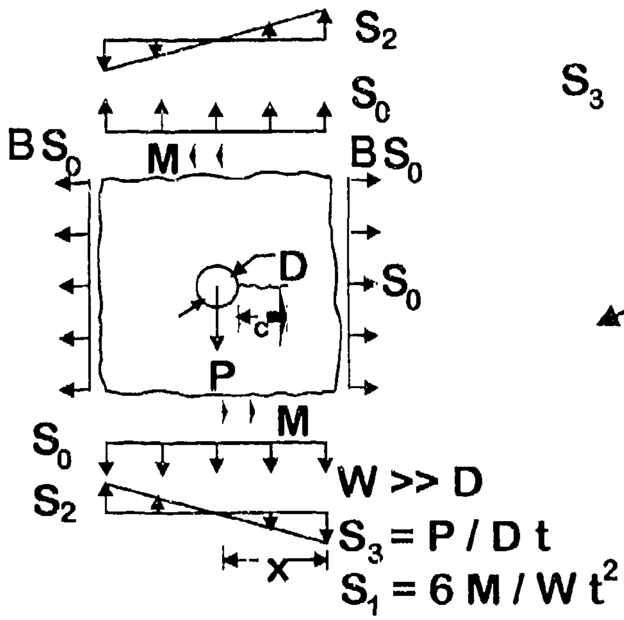
Through crack cases 7 & 8



Cross sectional view

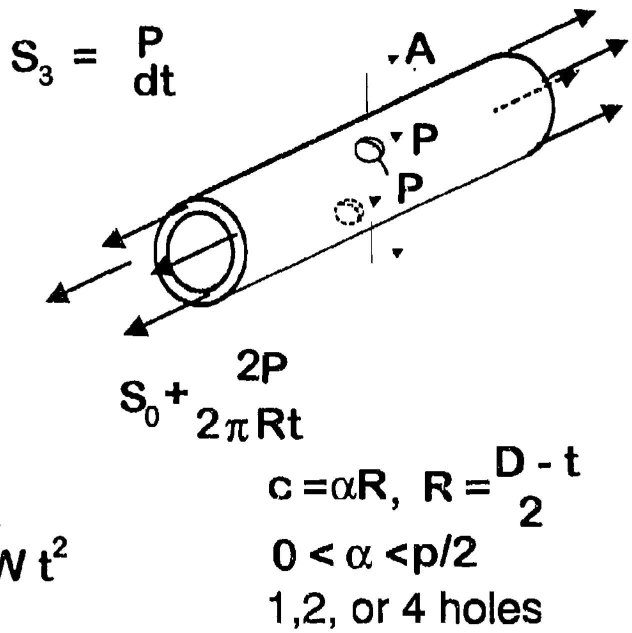
Figures 4-9 (TC07) and 4-10 (TC08))
[REF 4-2, Fig. 12]

TC09



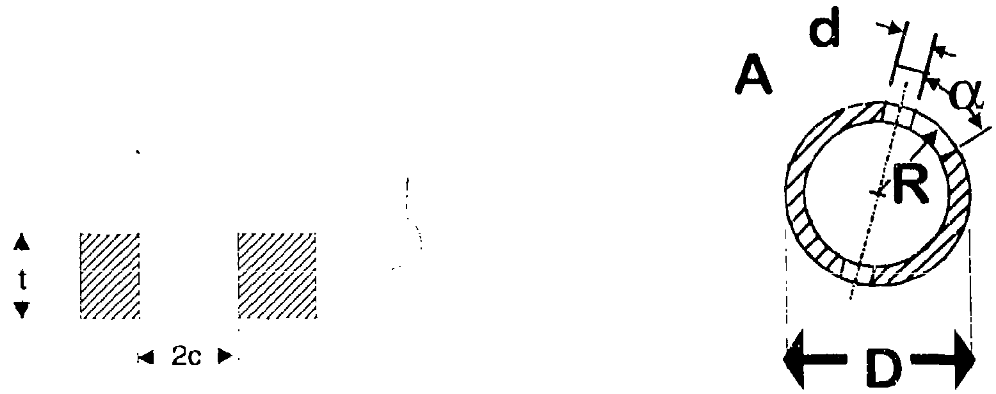
Through Crack from a
Hole in a Plate
Under Combined Loading

TC 10



Through Crack from a
Hole in a Cylinder
(Circumferential Direstion)

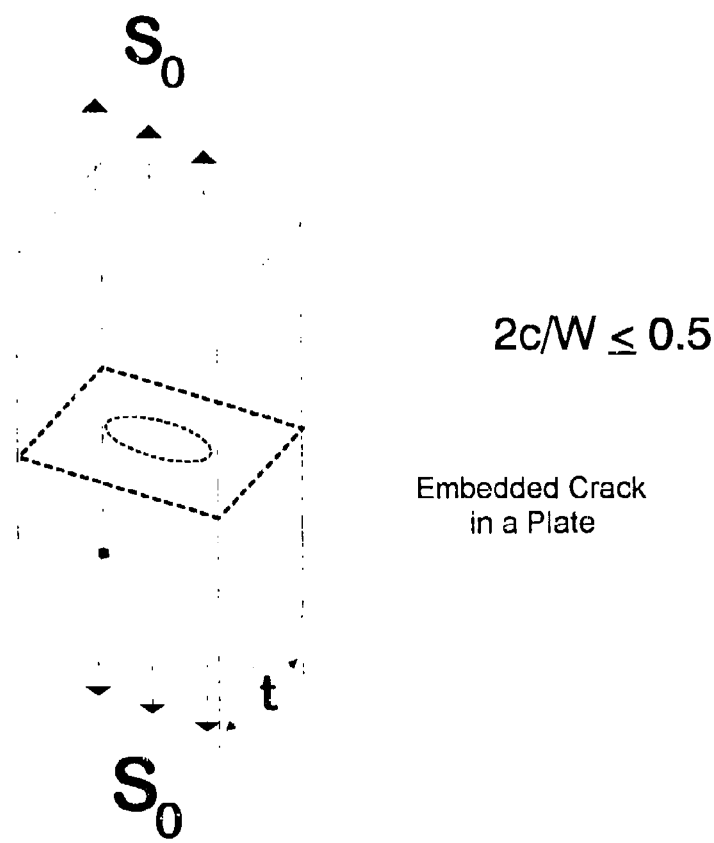
Through crack cases 9 & 10



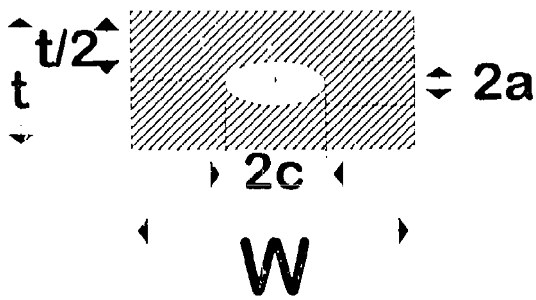
Cross sectional view A - A

Figures 4-11 (TC09) and 4-12 (TC010))
[REF 4-2, Fig. 13]

EC01



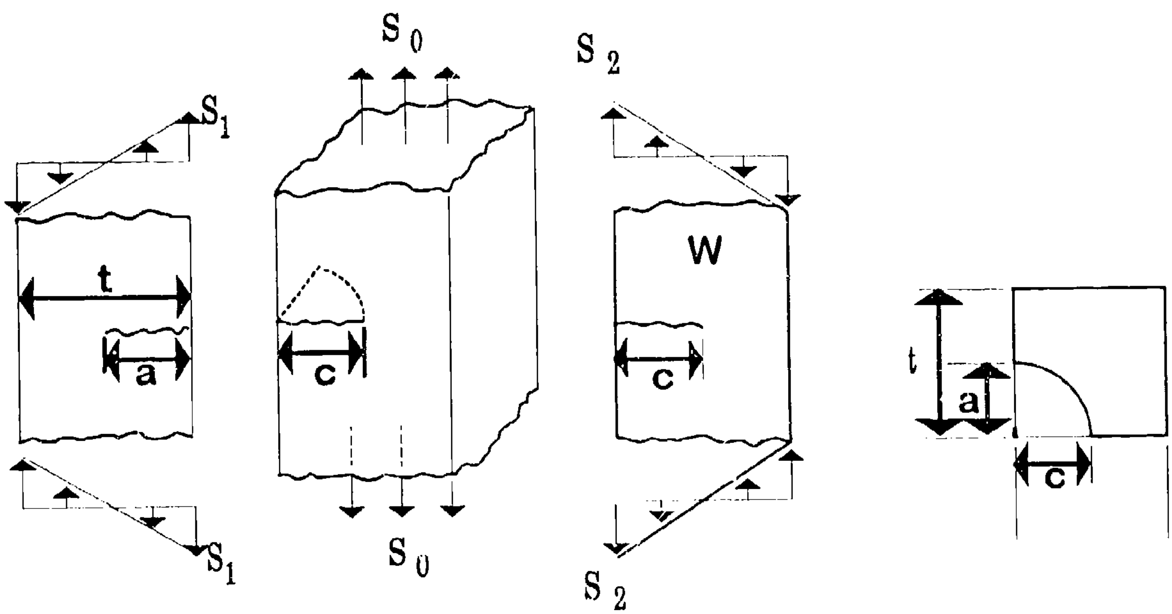
Embedded crack case 1



Cross sectional view

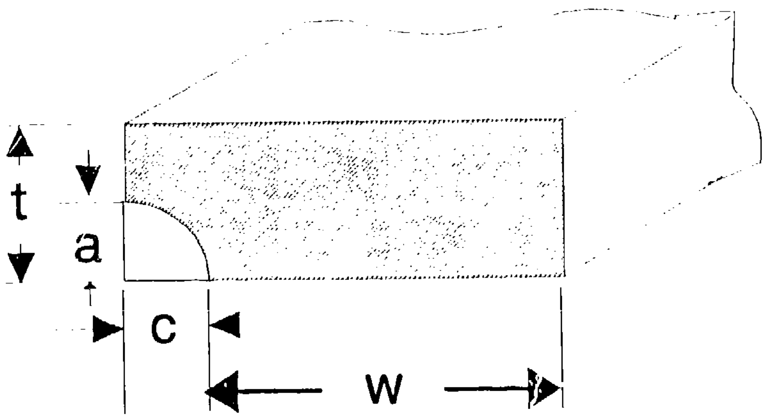
Figure 4-13 (EC01)
[REF 4-2, Fig. 14]

CC01



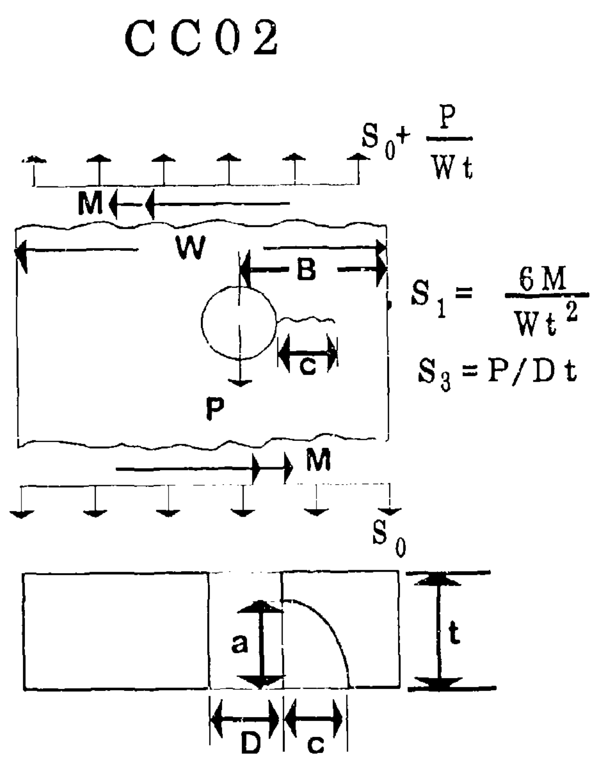
Corner Crack in
a Rectangular Plate

Corner crack case 1

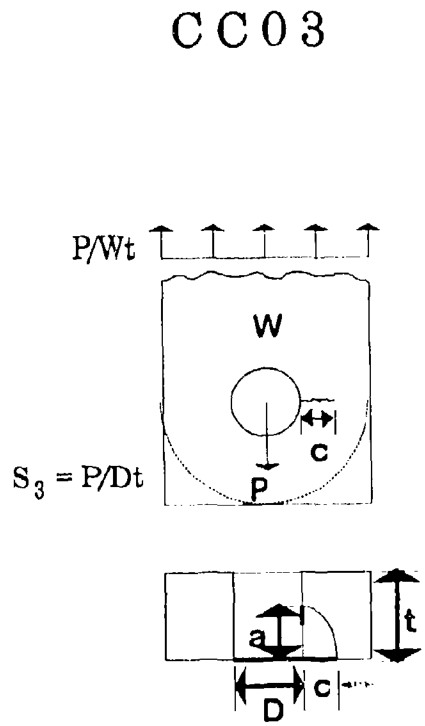


Cross sectional view

Figure 4-14 (CC01)
[REF 4-2, Fig. 15]

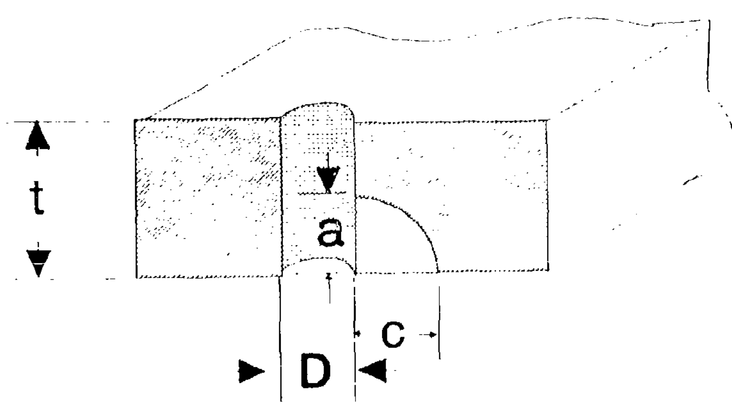


Corner Crack From a Hole in a Plate



Corner Crack From a Hole in a Lug

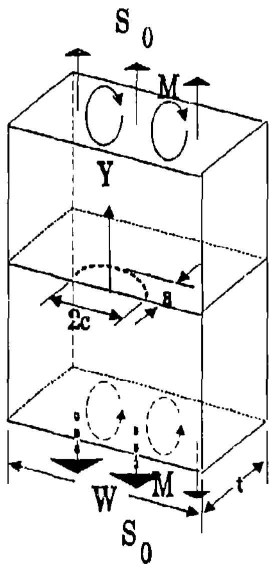
Corner crack cases 2 & 3



Cross sectional view

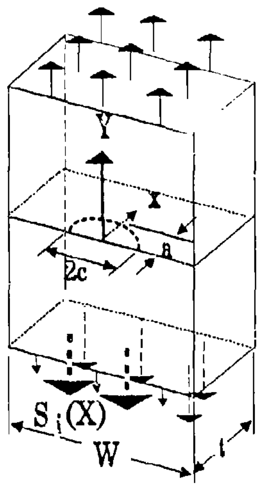
Figures 4-15 (CC02) & 4-16 (CC03)
[REF 4-2, Fig. 16]

SC01



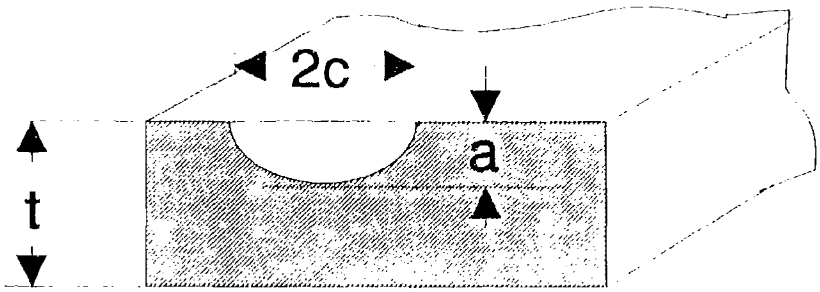
Surface Crack
in a Rectrangular Plate -
Tension and /or Bending

SC02



Surface Crack
In a Rectrangular Plate -
Nonlinear Stress

Surface crack cases 1 & 2

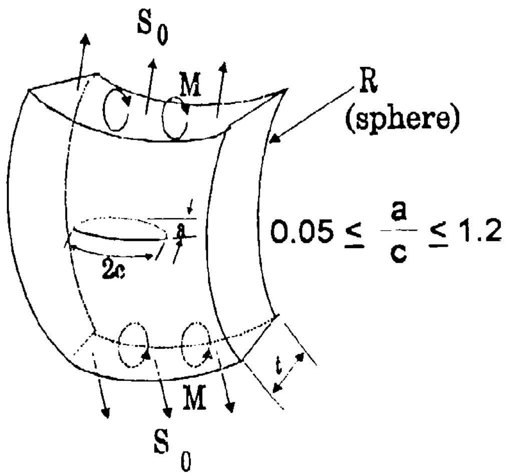


Cross sectional view

Figures 4-17 (SC02) & 4-18 (SC03)
[REF 4-2, Fig. 17]

SC03

internal or external crack



$$S_1 = \frac{6M}{Wt^2} \quad S_4 = p \text{ (internal pressure)}$$

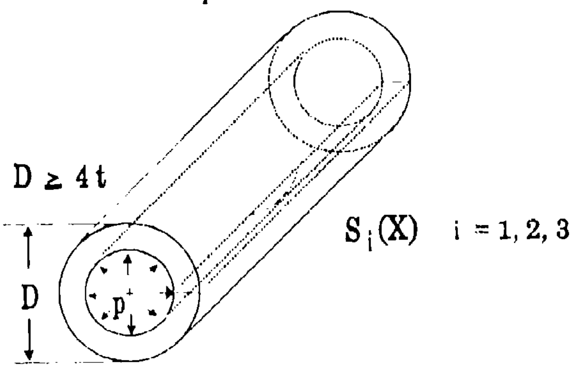
Surface Crack in
a Spherical Pressure Vessel

SC04

internal or external crack

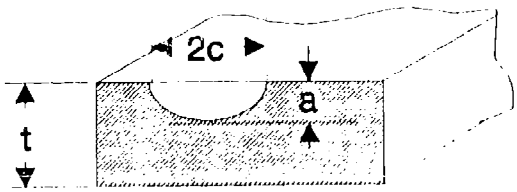
$S_0(X)$ = Stresses due to internal pressure, p

$S_i(X)$ = Other stresses

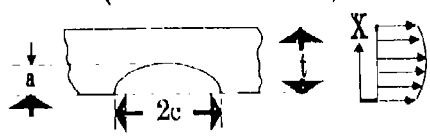


Longitudinal Surface Crack In
a Hollow Cylinder -
Nonlinear Stress

Surface crack cases 3 & 4



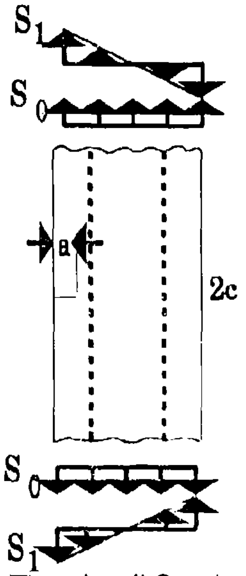
X = x/t
(from inner wall)



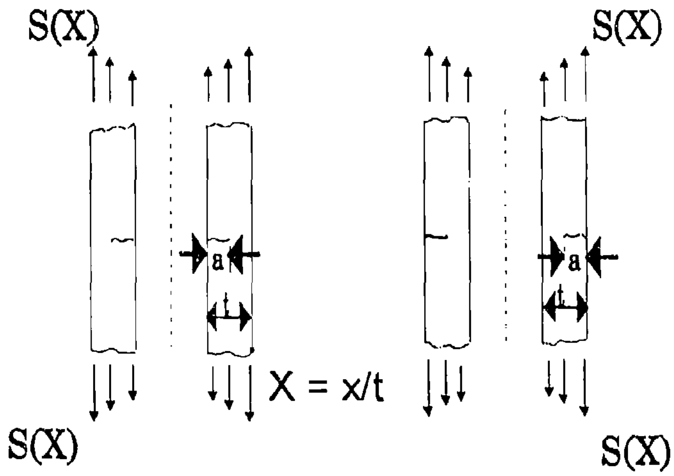
Cross sectional view

Figures 4-19 (SC03) & 4-20 (SC04)
[REF 4-2, Fig. 18]

SC05	SC06
internal or external crack	internal or external crack

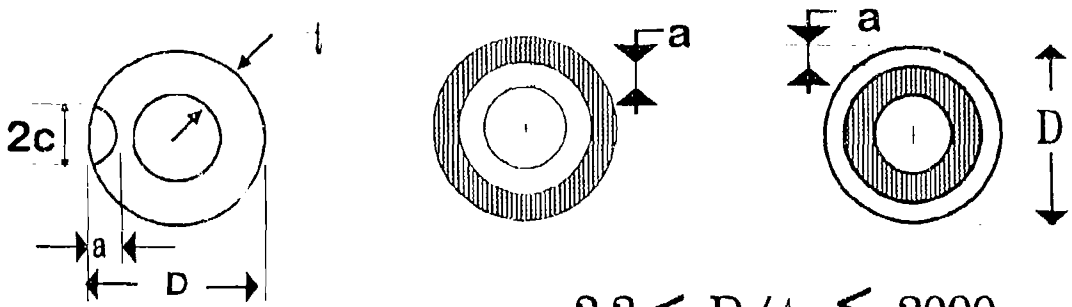


Thumbnail Crack
in a Hollow Cylinder



(from Inner wall)
Circumferential Crack
in a Hollow Cylinder -
Nonlinear Stress

Surface crack cases 5 & 6

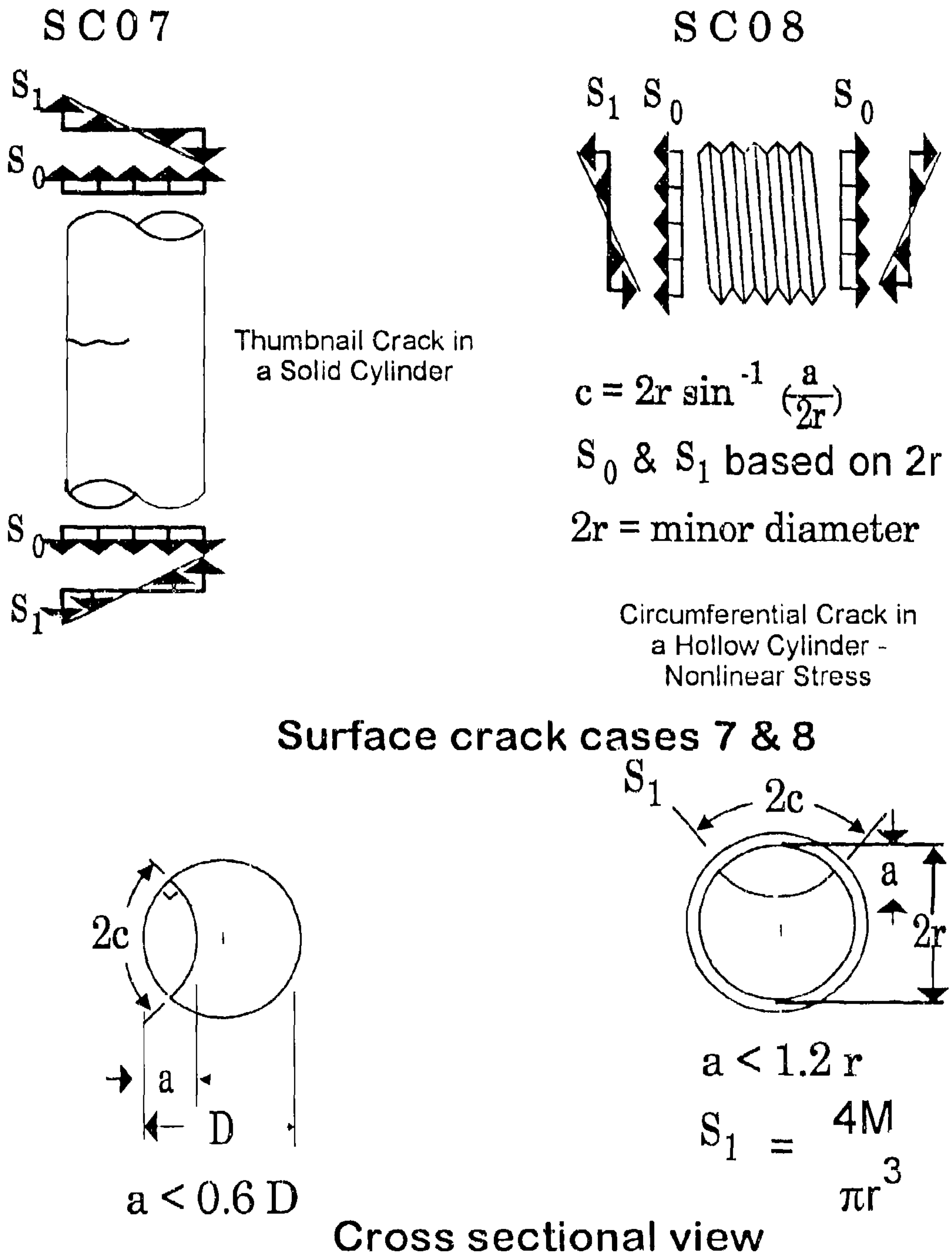


$2.2 \leq D/t \leq 2000$

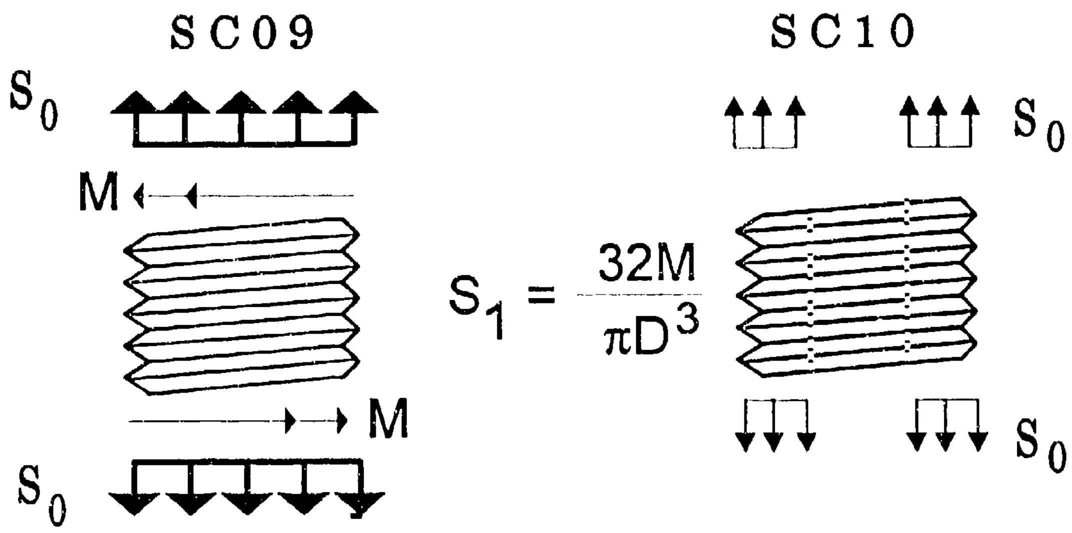
$0.05 > a/c \geq 1.2$

$D \geq 4\,t$ Cross sectional view

Figures 4-21 (SC04) & 4-22 (SC06)
[REF 4-2, Fig. 19]



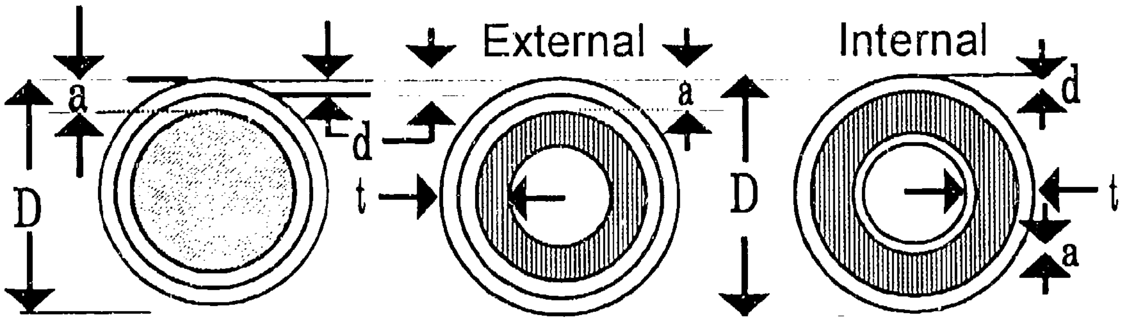
Figures 4-23 [SC07) & 4-24 (SC08)
[REF 4-2, Fig. 20]



Circumferential Crack at Thread Root in a Cylinder

Circumferential Crack in a Threaded Pipe - Nonlinear Stress

Surface crack cases 9 & 10



Cross sectional view

D = Major diameter
d = Thread depth
a = d + crack depth

D = Major diameter
d = Thread depth
a = d + crack depth

Figures 4-25 (SC09) & 4-26 (SC10)
[REF 4-2, Fig. 21]

Table 4-2 - Standard NDE Flaw Sizes for STS Payloads
US Customary Units [REF 4-2]

Crack Case	NDE Inspection Technique or Flaw Size Criterion	Thickness Range (in.)	**Crack depth, a	Size (in) crack length, c
TC01,TC06,TC07,TC08,TC10 (open surface)	EC	t ≤ 0.050	---	0.050
	P	t ≤ 0.050	---	0.100
	P	0.050 < t ≤ 0.075	---	0.15-t
	MP	t ≤ 0.075	---	0.125
TC02 (edge)	EC	t ≤ 0.075	---	0.100
	P	t ≤ 0.100	---	0.100
	MP	t ≤ 0.075	---	0.250
TC03 , TC04, TC05, TC09 (hole)	EC	t ≤ 0.075	---	0.100
	P	t ≤ 0.100	---	0.100
	MP	t ≤ 0.075	---	0.250
	HPD - driven rivet	any thickness	---	0.005
	HPD - other holes	t ≤ 0.050	---	0.050
EC01	R	0.025 ≤ t ≤ 0.107 t	0.35t	0.075
	R	> 0.107	0.35t	0.7t
	U	t ≤ 0.300	0.065	0.065
CC01 (edge)	EC	t > 0.075	0.075	0.075
	P	t > 0.100	0.100	0.100
	MP	t > 0.075	0.075	0.075
	U	t > 0.100	0.100	0.100
CC02, CC03 (hole)	EC	t > 0.075	0.075	0.075
	P	t > 0.100	0.100	0.100
	MP	t > 0.075	0.075	0.075
	U	t > 0.100	0.100	0.100
	HPD - not driven rivet	t > 0.050	0.050	0.050
SC01, SC02, SC03 (open surface)	EC	t > 0.050	0.020	0.100*
			0.050	0.050**
	P	t > 0.075	0.025	0.125*
			0.075	0.075**
	MP	t > 0.075	0.038	0.188*
			0.075	0.125**
	R	0.025 ≤ t ≤ 0.107 t	0.7t	0.075
		> 0.107	0.7t	0.7t
	U	t ≥ 0.100	0.030	0.150*
			0.06	0.065**
SC04, SC05	EC (ext & int)	t > 0.050	0.020	0.100*
			0.050	0.050**
	P (ext)	t > 0.075	0.025	0.125*
			0.075	0.075**
	MP(act)	t > 0.075	0.038	0.188*
			0.075	0.125**
	R (ext & int)	0.025 ≤ t ≤ 0.107 t	0.7t	0.075
		> 0.107	0.7t	0.7t
	U(ext & int)	t ≥ 0.100	0.030	0.150*
			0.065	0.065**

Table 4-2 - Standard NDE Flaw Sizes for STS Payloads (Concluded)
US Customary Units [REF 4-2]

Crack Case	NDE Inspection Technique or Flaw Size Criterion	Thickness Range (in.)	**Crack depth, a	Size (in) crack length, c
SC06	EC (ext & int)	t > 0.050	0.020	---
	P (ext)	t > 0.075	0.025	---
	MP(act)	t > 0.075	0.038	---
	R (ext & int)	0.025 ≤ t ≤ 0.107	0.7t	---
	U(ext & int)	t ≥ 0.100	0.030	---
SC07	EC	---	Eq18,19	0.050
	P	---	Eq18,19	0.075
	MP	---	Eq18,19	0.125
SC08 (rolled threads)	P	---	Eq18,19	0.075
SCO9, SC10 (machined threads)	max machining defect size	---	thd depth + 0.127	---

Notes:
EC = eddy current..................... (ET) R = X-radiographic...(RT) MP = magnetic particle......... (MT)
P = dye / fluorescent penetrant..(PT) U = ultrasonic...........(UT) HPD = hole penetration defect (max)
* minimum crack depth ** maximum crack depth *** 1 in. = 25.4 mm

Table 4-2 - Standard NDE Flaw Sizes for STS Payloads
SI Units [REF 4-2]

Crack Case	NDE Inspection Technique or Flaw Size Criterion	Thickness Range (mm)	**Crack depth, a	Size (mm) crack length, c
TC01,TC06,TC07,TC08,TC10 (open surface)	EC	t ≤ 1.270	---	1.270
	P	t ≤ 1.270	---	2.540
	P	1.270 < t ≤ 1.905	---	0.15-t
	MP	t ≤ 1.905	---	3.175
TC02 (edge)	EC	t ≤ 1.905	---	2.540
	P	t ≤ 2.540	---	2.540
	MP	t ≤ 1.905	---	6.350
TC03 , TC04, TC05, TC09 (hole)	EC	t ≤ 1.905	---	2.540
	P	t ≤ 2.540	---	2.540
	MP	t ≤ 1.905	---	6.350
	HPD - driven rivet	any thickness	---	0.127
	HPD - other holes	t ≤ 1 970	---	1.270
EC01	R	0.635 ≤ t ≤ 2.781	0.35t	1.905
	R	t > 2.781	0.35t	0.7t
	U	t ≥ 7.620	0.0651	1.651
CC01 (edge)	EC	t > 1.905	1.905	1.905
	P	t > 2.540	2.540	2.540
	MP	t > 1.905	1.905	1.905
	U	t > 2.540	2.540	2.540
CC02, CC03 (hole)	EC	t > 1.905	1.905	1.905
	P	t > 2.540	2.540	2.540
	MP	t > 1.905	1.905	1.905
	U	t > 2.540	2.540	2.540
	HPD - not driven rivet	t > 1.270		
SC01, SC02, SC03 (open surface)	EC	t > 1.270	0.508	2.540*
			1.270	1.270**
	P	t > 1.905	0.635	3.175*
			1.905	1.905**
	MP	t > 1.905	0.965	4.755*
			1.905	.175**
	R	0.635 ≤ t ≤ 2.781	0.7t	1.905
		t > 2.781	0.7t	0.7t
	U	t ≥ 2540	0.762	1.270*
			0.06	1.651**
SC04, SC05	EC (ext & int)	t > 1.270	0.508	2.540*
			1.270	1.270**
	P (ext)	t > 1.905	0.635	3.175*
			1.905	1.905**
	MP(act)	t > 1.905	0.965	4.755*
			1.905	3.175**
	R (ext & int)	0.635 ≤ t ≤ 2.781	0.7t	1.905
		t > 2.781	0.7t	0.7t
	U(ext & int)	t ≥ 2540	0.762	1.270*
			1.651	1.651**

Table 2 - Standard NDE Flaw Sizes for STS Payloads SI Units (Concluded) [REF 2]

Crack Case	NDE Inspection Technique or Flaw Size Criterion	Thickness Range (mm)	**Crack depth, a	Size (mm) crack length, c
SC06	EC (ext & int)	t > 1.270	0508 0.635	---
	P (ext)	t > 1.905	0.965	---
	MP(act)	t > 1.905	0.7t	---
	R (ext & int)	0.635 ≤ t ≤ 2.781	0.762	---
	U(ext & int)	t ≥ 2540		---
SC07	EC	---	Eq18,19	1.270
	P	---	Eq18,19	1.905
	MP	---	Eq18,19	3.175
SC08 (rolled threads)	P	---	Eq18,19	1.905
SCO9, SC10 (machined threads)	max machining defect size	---	thd depth + 0.127	---

Notes:
EC = eddy current..................... (ET) R = X-radiographic...(RT) MP = magnetic particle........... (MT)
P = dye / fluorescent penetrant..(PT) U = ultrasonic...........(UT) HPD = hole penetration defect (max)
* minimum crack depth ** maximum crack depth *** 1 in. = 25.4 mm

4.4 SUMMARY

Initial flaw / crack size "generic" values for NDE capabilities in design have been derived from "prior art" and have been incorporated into modern design / analysis tools. The initial flaw / crack size "generic" values are periodically updated and expanded to reflect advances in NDE technology. Design values are included in this data book for the convenience of the user (Courtesy of NASA - JSC). Validation of NDE capabilities in specific applications are the responsibility of the user for both "generic" and "special NDE" procedures and applications.

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5. NDE CAPABILITIES DATA FORM AND PRESENTATION

5.0 GENERAL

The usual forms of reporting nondestructive evaluation (NDE) data are "Hit / Miss" (Pass / Fail) or a recorded signal response. "Hit / Miss" reporting is the resolution of NDE procedure application and interpretation / discrimination in accordance with established acceptance criteria. Only the decision result is recorded and, in many cases, no additional record of the inspection performance levels are preserved. Signal response level recording enables post process interpretation and discrimination and provides an opportunity for review by multiple technologists and for discrimination using varying levels of acceptance criteria. Discrete signal response data are easily obtained for some NDE processes while others are more difficult to record due to the nature and/or multiple processing steps involved in completing the process. Automated NDE processes are more amenable to process parameter recording, recording of process results in the form of an image or data stream, and in recording the accept / reject decision using the programmed discrimination parameters.

The objective of quantifying NDE capabilities is to relate the output of the NDE process / procedure to a desired (or undesired) characteristic of the test object. A multitude of inspections are performed to "detect cracks" as a characteristic of primary importance in structural integrity analyses. Although other characteristics are measured and assessed, crack detection is the primary focus of data presented herein. Quantification of detection as a function of crack size is the output of most NDE capabilities characterization. Such quantification answers a basic question "How large a crack might be missed?" ("How small a crack can be detected?"). The second part of the query is "How confident are we in the answer provided?"

Unfortunately, all cracks are not created equal and cracks of equal size can provide widely varying responses with some NDE procedures. The detection capability measured is thus specific to a given crack type (fatigue, stress corrosion, tear, etc.). It is thus necessary to select / produce cracks that are representative of the type to be detected in the applied NDE procedure. Artificially induced fatigue cracks are frequently used in NDE capabilities assessments because: they are relatively easy to produce and reproduce; they are frequently the type of crack that must be detected by service life inspections; and because they are one of the most difficult crack types to detect.

If the length of a rod is repetitively measured with a precision instrument and the results recorded, a range of values will be obtained that reflect variability in the measurement process. In like manner, repetitive NDE measurements on a single crack will produce a range of values that are characteristic to the measurement process. If the basis for NDE acceptance (threshold) is set at a level that is within the range of measurement variance for an NDE procedure, a variation on output (accept / reject) will result and useful discrimination will not be provided.

The NDE capabilities value reported must thus be tempered by the type of crack (test artifact) used in the test; by the NDE procedure used, and by the discrimination level used as the basis for accept / reject ("Hit / Miss"). Confidence in the value obtained will be characterized by the number of cracks (and crack size distribution) used to obtain the result.

5.1 COLLECTION AND PRESENTATION OF NDE CAPABILITIES DATA

The established and accepted metric for characterizing the capability of an NDE procedure is a probability of detection (POD) curve. A POD curve is produced by:

- Applying a specific NDE procedure to a large number of cracks (artifacts) of varying size that represent the artifact to be detected in a production application;
- Correlating and recording the results of inspection with each crack size;
- Analyzing the data by fitting the results to a model that is representative of the type of data produced; and
- Plotting the results in the form of probability of detection as a function of flaw size.

The analysis, model and plotting procedure differ with type of data produced ("Hit / Miss" or signal response level). A typical POD curve is shown in Figure 5-1.

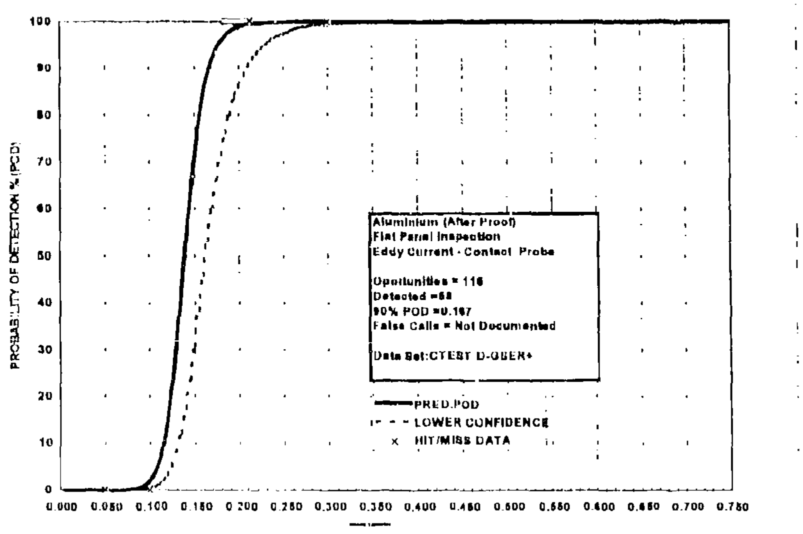

FIGURE 5-1 A Typical Probability of Detection Curve

A lower 95% confidence bound may be added to reflect the calculated confidence based on the crack sample size, distribution and results obtained. The actual crack size individual detection result is plotted as an "X"; at 100% if detected and at 0% if missed ("Hit / Miss data only). Identification of other features of the data set may be added to uniquely describe and identify the plot.

The single valued parameter that is used to characterize the procedure is that crack size at which the POD reaches the 90% level. The single valued parameter that is often quoted in validation requirements is that crack size at which the lower 95% confidence line reaches the 90% level (90/95 value).

6. DESIGN OF THE EXPERIMENT FOR NDE CAPABILITIES ASSESSMENT

6.0 OVERVIEW

The "design of the experiment" to characterize the capabilities of an NDE procedure is important to producing "well behaved" data and to provide confidence in the results obtained. Critical factors in design of the experiment are:

- Selection / production of cracks that are representative of the NDE application and test object;
- Avoid "resampling" of the same crack since an important element of the characterization is the crack to crack variation.
- Producing a crack size distribution such that the majority of cracks are at a size near the threshold value (90% detection threshold); (Note: The expected threshold value may not be the actual value produced and "ill behaved" data may be produced if the measured threshold value differs significantly from that anticipated). This data book is expected to be of significant aid in selecting an appropriate crack size distribution for user characterization of similar NDE procedures;
- Establishing controlled NDE procedures that will be used in damage tolerance inspections; (Attention should be given to assuring that the NDE parameters are controlled to provide the maximum possible reproducibility and repeatability of results obtained by application of the NDE procedure. The POD method of NDE procedure characterization has been of significant value in increased understanding of NDE processes and significant control parameters);
- Data collection under all variations of conditions expected in application of the NDE procedure;
- Disciplined and accurate data collection to relate detection to the test object artifact being assessed;
- Data analysis that is consistent with "prior art and knowledge"; and
- Data documentation and presentation in sufficient detail to enable and anticipate duplication of results, if the experiment were repeated.

The POD result / metric provided is specific to the test object, test artifact and NDE procedure used and reflects crack-to-crack variations in the test set, NDE procedure variations in application, and acceptance level / discrimination variations used in interpretation of the NDE process output. POD characterization has evolved as a useful NDE engineering tool for NDE procedure design and development; for comparison of various NDE procedures; for validation of specific NDE procedures; and for personnel skill qualification.

For more detailed information on design of experiment and methodology for characterizing NDE procedures by the POD method, see REFERENCE 6-1. For a

historical review of documents describing development and refinement of POD characterization, see REFERENCES 6-2 thru 6-4.

6.1 TRADE-OFFS BETWEEN IDEAL AND PRACTICAL NDE PROCEDURE DEMONSTRATION AND VALIDATION

Although POD characterization is a recognized method of NDE procedure characterization and validation, variations and alternates to the POD method may satisfy the specific needs / requirements of the user. Three variations on NDE procedure validation are discussed in the following sections. The user must select the method that best suits the application.

6.2 MODELING POD RESPONSE , "$\hat{a}$ (a-hat)" VERSUS "a" DATA

The fidelity of, and options for use of, POD data are increased by quantification and documentation of process parameters and signal response levels used in the detection and discrimination processes. If signal amplitudes are quantified and used as the basis for acceptance / discrimination, post analysis and processing at different threshold discrimination levels may be used to optimize NDE procedure performance. Methodology has been developed and documented for use of the measured response "$\hat{a}$" versus actual crack size "a" by fitting the data to a POD model. For a detailed discussion of this method of POD modeling, see REFERENCE 6-1. Software for this method of analysis is available through the United States Air Force.

For NDE procedures that produce a precision output, this analysis method enables NDE procedure characterization with fewer observations / data points than is possible using "hit / miss" data. This method also provides a means of linking data obtained on various crack artifacts to actual crack response and thus has significant value in predicting NDE capabilities for defects that cannot be readily produced. In like manner, linking NDE procedure capabilities to quantified signal response levels provides a means of predicting POD capabilities based on model based prediction of response levels for a given NDE procedure.

6.3 "ACCEPT / REJECT" ("HIT / MISS") DATA

Many NDE procedures depend on process control and pattern recognition and discrimination by a human operator to produce an accept / reject ("hit / miss") output. The output is binomial in nature and a point estimate of detection capability at a single crack size (POD (a)) may be obtained for large sample sizes. The point estimate of detection does not provide information on NDE procedure or discrimination level variance and is thus applicable to only one point on the POD curve. A lognormal formulation of a POD (a) model was a natural consequence of observed behavior of NDE data and fitting of data to a lognormal model may be completed by the use of a maximum likelihood procedure to estimate the parameters of the model, given the actual data

observed. This method of analysis was introduced by Berens and Hovey in 1981 [REF 6-5 and 6-6], and is the basis for most variations that have been introduced since then. The probability of detection (POD (a)) is expressed as:

$$POD(a) = F(\alpha + \beta(\log (a)),$$

where α and β are parameters to be fit to the data and F is an increasing function of a.

The cumulative lognormal distribution function is approximated by the log - odds model and the data may be described by:

$$POD(a) = \frac{\exp[\alpha + \beta \ln(a)]}{1 + \exp[\alpha + \beta \ln(a)]}$$

where a = crack length.

The maximum likelihood is used to estimate the α and β parameters of the model.

The maximum likelihood / log odds method of analysis was used for all "Hit / Miss" data presented in this data book.

6.4 THE POINT ESTIMATE (29/29) METHOD OF NDE PROCEDURE DEMONSTRATION / VALIDATION

If the capability is known, a subset of the full POD process may be used to provide a measure of confidence in the output of an NDE procedure. The binomial nature of "Hit / Miss" data suggests that data obtained from cracks of a single size may be used to provide confidence that such cracks will be detected by application of the procedure. From sampling theory, 29 successes out of 29 trials provides a 90% confidence that the same result would be obtained if the experiment / measurement were reported an infinite number of times (Note: This procedure does not presume that the result obtained is absolute, but establishes a measured confidence (prediction) that the procedure will provide the required detection and discrimination [REF 6-7]. The point estimate method is particularly useful in skill qualification of personnel, when the general capabilities of the NDE procedure are known. This method is used in both procedure qualification and personnel qualification as a part of the NASA Space Shuttle program [REF 6-8]. Care is taken to assure that the test artifacts (cracks) are representative of the population to be assessed and that NDE procedure application is consistent with the test conditions used in qualification.

The point estimate procedure is the least information rich of those in common use. The point estimate test provides no information on the margin that is inherent to the NDE procedure and care must be taken to assure that the point estimate qualification is above

the threshold limit for the procedure. If the point estimate test is failed, no information is provided for use in process improvement for process acceptability. Processes that are known to be near the limit of detection / discrimination, and detection requirements that exceed "prior art", are not candidates for qualification by this method.

6.5 POD MODELS AND ANALYSIS VARIATIONS

The economics of NDE procedure characterization by the POD method and "ill behaved" results for some data provide a continuing challenge for development of better methods of analysis and modeling. "Misses" at large crack sizes and false calls (detection call when no flaw is present) are particularly troublesome and have been addressed by various workers. Analysis and presentation of data in this document have been analyzed by both variations of the "maximum likelihood / log odds" method in their original presentation form. Results presented herein have all been produced by the same "maximum likelihood / log odds" method.

The user is referred to REFERENCES 6-9 through 6-13 for exploration of alternate analysis methods. A common baseline method is, however, recommended for comparison of respective results.

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7. NDE PROCESS PRINCIPLES AND PRACTICES

7.0 GENERAL

Nondestructive evaluation (NDE) technology denotes application of a diverse array of nondestructive processes to monitor / measure direct material response. The measured response is related to a desired material property or test object attribute by "interpretation." NDE methods that are generally recognized as elements of "mainstream / classical" NDE technology are:

- Visual inspection;
- Liquid penetrant inspection;
- Magnetic particle inspection;
- Radiographic inspection (X-ray and gamma ray)
- Electromagnetic inspection;
- Ultrasonic inspection; and
- Thermographic inspection.

Although each method is dependent on different "first principles" in both application and output, repeatable and reproducible NDE results depend on specific understanding and control of the:

- Evaluation materials;
- Evaluation equipment;
- Evaluation procedure;
- The environment in which the procedure is completed;
- Calibration / baseline reference artifact and procedure
- Applied acceptance criteria; and
- Human factors

It is important to note that "Human Factors" are listed last; if materials, equipment and process parameters are not controlled, the human operator has little chance of providing a consistent level of discrimination. Conversely, knowledgeable and skilled human operators are essential to the discrimination. No NDE process or procedure produces absolute discrimination of "all anomalies" but the end output of a procedure may be quantified and the discrimination (anomaly / flaw detection) capability may be measured, analyzed, quantified and documented. The use of the probability of detection (POD) method of NDE procedure characterization has resulted in new understanding of the NDE processes and factors that would improve the process capability, reproducibility and repeatability.

7.1 NDE PROCESS AND PROCESS VARIANCE

The diverse nature of different NDE processes results in different sources of variance and resultant impact on detection output capabilities. For example, a manually applied liquid penetrant process is dominated by the skill of the operator in process application and interpretation. An automated eddy current process is dominated by calibration, instrument and procedure variances. It is important to recognize the source of variance in each NDE process and to take the nature of the variance and process control into account in applying margins to the NDE processes. Table 7-1 shows typical dominant sources of variance for the following NDE processes:

- Liquid penetrant inspection;
- Magnetic particle inspection;
- Radiographic inspection (X-ray and gamma ray);
- Electromagnetic inspection;
- Ultrasonic inspection; and
- Thermographic inspection.

Table 7-1 DOMINANT SOURCES OF VARIANCE IN NDE PROCEDURE APPLICATION

	Materials	Equipment	Procedure	Calibration	Criteria	Human Factors
Liquid Penetrant	X		X			X
Magnetic Particle	X	X	X			X
X-ray	X	X	X			X
Manual Eddy Current		X	X	X	X	X
Automatic Eddy Current		X	X	X	X	
Manual Ultrasonic		X	X	X	X	X
Automatic Ultrasonic		X	X	X	X	
Manual Thermo -		X	X	X		X
Automatic Thermo		X	X	X	X	

NDE methods and procedures are selected using a variety of practical implementation criteria. The lowest cost method that produces the required result is usually the method of choice. Part of the cost consideration must be the cost of qualifying / validating the capabilities of the method and the cost of maintaining such qualification. The data included herein are intended to be an aid to method / procedure selection and implementation.

7.2 LIQUID PENETRANT INSPECTION

The liquid penetrant NDE method is applied to detection of anomalies that have a capillary opening to the test object surface. General process steps include:

1. Test object cleaning to remove both surface and materials in the capillary opening;
2. Application of a penetrant fluid and allowing a "dwell" time for penetration into the capillary opening;
3. Removal of surface penetrant fluid without removing fluid from the capillary;
4. Application of a "developer" to draw penetrant fluid from the capillary to the test object surface (the "developer" provides a visible contrast to the penetrant fluid material);
5. Visually inspecting the test object to detect, classify and interpret the presence, type and size (magnitude) of the penetrant indication. (NOTE: Some automated detection systems are in use and must be characterized as special NDE processes).

The nature of this NDE method demands attention to material type, surface condition and rigor of cleaning. It is obvious that processes that modify surface condition must be applied **after** penetrant processing has been completed. Such processes include, conversion coatings, anodizing, plating, painting, shot peening, etc. In like manner, mechanical processes that "smear" the surface and close capillary openings must be followed with "etch" and neutralization steps **before** penetrant processing. Although there is disagreement on the requirement for etching after machining processes for "hard materials", experimental data indicate that all mechanical removal processes result in a decrease in penetrant detection capabilities.

Liquid penetrant inspection can be performed with little capital expenditure; materials used are low in cost per use; is applicable to complex shapes; and is widely used for general product assurance. The capability of this method is highly material, procedure and operator skill / experience dependent. No permanent record of inspection is provided by the process.

COST OF INSPECTION	LOW
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	HIGH

* NOTE: In commercial practice, liquid penetrant inspection may be denoted by the "Trade Name" of the materials used in the process. For example, "Zyglo" is a trade name for a group of fluorescent penetrant materials marketed by the "Magnaflux Corporation" and does not adequately describe the process to be applied.

7.3 MAGNETIC PARTICLE INSPECTION

Magnetic particle inspection is applied to the detection of surface connected or near surface anomalies in test objects that are made from materials that sustain a magnetic field. General process steps include:

1. Test object cleaning to remove surface contaminants;
2. Inducing a magnetic field in the object;
3. Applying a fluid or powder containing finely divided particles that are attracted by the presence of a discontinuity in a magnetic field;
4. Visually inspecting the test object to detect, classify and interpret the presence, type and size (magnitude) of indication (accumulation of magnetic particles along a discontinuity in a magnetic field).

Special equipment is required to induce the required magnetic field(s). Procedure development and process control are required to use the proper voltage, amperage, mode of induction, etc. Test object materials must be capable of sustaining an induced magnetic field during the period of inspection. Concentration and mode of application of the magnetic particles must be controlled. Material characteristics or surface treatments which result in variable magnetic properties will decrease detection capabilities.

Magnetic particle inspection can be performed with little capital expenditure; materials used are low in cost per use; is applicable to complex shapes; and is widely used for general product assurance. The capability of this method is highly material, test equipment, procedure and operator skill / experience dependent. No permanent record of inspection is provided by the inspection process.

COST OF INSPECTION	LOW
COST OF EQUIPMENT	MODERATE
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	HIGH

* NOTE: In commercial practice, magnetic particle inspection may be denoted by the "Trade Name" of the materials used in the process. For example, "Magnaflux" is a trade name for a group of inspection equipment and materials marketed by the "Magnaflux Corporation" and does not adequately describe the process to be applied.

7.4 X-RADIOGRAPHIC INSPECTION

X-radiographic (X-ray) inspection is applied to the detection of surface connected and internal anomalies in test objects and to assess the internal configuration of test objects. General process steps include:

1. Locating a sheet of X-ray sensitive film on one side of the test object;
2. Locating an X-ray source (X-ray tube) on the opposite side of the test object;
3. Activating the X-ray source to "expose the film" in a through transmission mode;
4. Developing the film;
5. Visually inspecting the resultant film image to detect, classify and interpret the presence, type and size (magnitude) of included indications.

Special equipment, special exposure facilities and special safety precautions (including licenses) are required to perform the inspection. Procedure development and process control are required to ascertain the proper voltage, amperage, exposure time, film type, etc. Detection of crack-like anomalies is highly dependent on the exposure geometry and on the orientation of the crack with respect to the incident radiation.

X-radiographic inspection requires considerable capital expenditure; materials used are moderate in cost per use; is applicable to complex shapes; and is widely used for general product assurance. The capability of this method is highly material, test equipment, procedure and operator skill / experience dependent. A permanent record of inspection is provided in the form of a film image.

COST OF INSPECTION	MODERATE
COST OF EQUIPMENT	HIGH
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	HIGH

* NOTE: X- radiographic inspection and gamma radiographic inspection using a radioactive source involve essentially the same set-up and exposure procedures, but differ significantly in inspection capability. Both methods require extensive procedures for assuring the safety of human operators.

7.5 EDDY CURRENT INSPECTION

Eddy current methods of inspection are applied to measure a variety of material characteristics and conditions. They are applied in the flaw detection mode for the detection of surface connected or near surface anomalies in test objects. Test objects must be electrically conductive and be capable of uniform contact by an eddy current probe. General process steps include:

1. The eddy current probe is placed in contact with the test object;
2. An alternating magnetic field is induced in the probe by an alternating current in the probe coil;
3. Eddy current flow is induced in the test object;
4. The magnitude and phase of the induced current flow is sensed by a secondary coil in the probe or by change of inductance in the probe;
5. A localized change in induced current flow indicates the presence of a discontinuity (crack) in the test object.
6. The size (length) of the crack is indicated by the extent of the response change as the probe is scanned along the test object.

Special equipment and specialized probes are required to perform the inspection. Procedure development, calibration artifacts and process control are required to assure reproducibility of response in the selected test object. The method is a volume inspection process and therefore loses resolution near edges and at locations of non-uniform geometry change.

Manual (hand) scanning is performed using instruments that have a needle (deflection) or oscilloscope read-out. Operator interpretation is made by pattern recognition, signal magnitude and respective hand-scan position. Variations in instrument read-out and variations in scanning can be significant. No permanent record of inspection is provided

Automated scanning is performed using an instrumented scanner which keeps track of probe position and automated signal detection (phase and amplitude) such that a response map of the test object surface can be generated. Resolution of the inspection system is somewhat dependent on the fidelity of the scan index and on the filtering and signal processing that are applied in signal detection. A scan map and/or commented report may be generated by automated eddy current scanning and instrumentation systems.

MANUAL (HAND) SCAN

COST OF INSPECTION	LOW
COST OF EQUIPMENT	MODERATE
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	MODERATE
PROCESS VARIANCE / MARGIN REQUIREMENTS	MODERATE

AUTOMATED SCANNING AND INSPECTION

COST OF INSPECTION	MODERATE
COST OF EQUIPMENT	HIGH
OPERATOR SKILL REQUIREMENTS	MODERATE
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	LOW

* NOTE: Eddy current methods are also known as electromagnetic methods.

7.6 ULTRASONIC INSPECTION

Ultrasonic methods of inspection are applied to measure a variety of material characteristics and conditions. They are applied in the flaw detection mode for the detection of surface and internal anomalies in test objects. Test objects must support propagation of acoustic energy and have a geometric configuration that allows the introduction and detection of acoustic energy in the reflection, transmission or scattered energy configurations. General process steps include:

1. An ultrasonic transducer is located in contact or in close proximity to the test object;
2. The transducer is energized in a pulsed mode to direct and propagate acoustic energy into the test object;
3. Acoustic energy is transmitted, reflected and scattered within the test object.
4. Energy within the test object is transmitted or redirected by internal interfaces (test object geometry features or internal anomalies);
5. Transmitted or redirected energy from the test object is detected by a transducer located on or near the test object;.
6. The transmitted or redirected energy is analyzed in the time and /or frequency domains and interpretation of the internal condition of the test object is made by the pattern and amplitude features..

Special equipment and specialized probes are required to perform the inspection. Procedure development, calibration artifacts and process control are required to assure reproducibility of response in the selected test object. The method is a surface and

volume inspection process and procedures are varied to increase sensitivity and resolution of specific test object features.

Manual (hand) scanning is performed using instruments that have an oscilloscope type read-out. Operator interpretation is made by pattern recognition, signal magnitude, timing and respective hand-scan position. Variations in instrument read-out and variations in scanning can be significant. No permanent record of inspection is provided

Automated scanning is performed using an instrumented scanner which keeps track of probe position and automated signal detection (time, phase and amplitude) such that a response map of the internal structure of the test object can be generated. Resolution of the system is somewhat dependent on the fidelity of the scan index and on the filtering and signal processing that are applied in signal detection. A scan map and/or commented report may be generated by automated ultrasonic scanning and instrumentation systems.

MANUAL (HAND) SCAN

COST OF INSPECTION	LOW
COST OF EQUIPMENT	MODERATE
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	MODERATE
PROCESS VARIANCE / MARGIN REQUIREMENTS	MODERATE

AUTOMATED SCANNING AND INSPECTION

COST OF INSPECTION	MODERATE
COST OF EQUIPMENT	HIGH
OPERATOR SKILL REQUIREMENTS	MODERATE
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	LOW

7.7 THERMOGRAPHIC INSPECTION

Thermographic inspection methods are applied to measure a variety of material characteristics and conditions. They are generally applied in the flaw detection mode for the detection of interfaces and/or variation of the properties on interfaces within layered test objects. Test objects must be thermally conductive and the test object surface must be reasonably uniform in color and texture. General process steps include:

1. A pulse of thermal energy is introduced into the test object;
2. Energy is diffused within the test object according to the thermal conductivity, the thermal mass, inherent temperature differentials and the time of observation / measurement;

3. The thermal state (temperature) of the test object surface is monitored by a thermographic (scanner) camera with capability for detection in the infrared energy spectrum;
4. Interpretation is completed by visually monitoring the relative surface temperature as a function of time and relating temperature differences in the time domain to the internal condition and/or structure of the test object;
5. A relative change in surface temperature (at a predetermined time) is indicative of a change in continuity or connectivity (unbond) in a bonded structure;
6. The size (area map) of an unbond is indicated by the location of the temperature gradient on the surface at a specific time and is modified by comparison with responses from similar test objects with similar geometries and thermal mass.

Special equipment is required for both introducing the thermal pulse and for monitoring the thermal condition of the surface as a function of time. Procedure development, calibration artifacts and process control are required to assure reproducibility of response in the selected test object. The method is a volume inspection process and therefore loses resolution near edges and at locations of non-uniform geometry change.

Manual inspection is performed using manual control of the thermal pulse process and human observation and interpretation of the thermal images produced as a function of time. A false color, thermal map presentation may be used to aid in discrimination of fine image features and to aid in pattern recognition. The thermal map may be recorded on video tape as a function of time. No permanent record of image interpretation is provided

Automated scanning is performed using an instrumented scanner which reproducibly introduces a pulse of thermal energy into the test object and synchronizes pulse introduction with the "start time" for use in automated image read-out. Automated read-out is effected via pre-programmed digital image processing and is test object and inspection procedure specific.

MANUAL (HAND) SCAN

COST OF INSPECTION	LOW
COST OF EQUIPMENT	HIGH
OPERATOR SKILL REQUIREMENTS	HIGH
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	MODERATE

AUTOMATED SCANNING AND INSPECTION

COST OF INSPECTION	LOW
COST OF EQUIPMENT	HIGH
OPERATOR SKILL REQUIREMENTS	MODERATE
PROCESS CONTROL REQUIREMENTS	HIGH
PROCESS VARIANCE / MARGIN REQUIREMENTS	LOW

7.8 NDE PROCESS OUTPUT

When an NDE process is applied to a test object, the output response to an anomaly within the test object will depend on the form of detection (pattern recognition), the magnitude of the feature that is used in detection, and the relative response magnitude of the material surrounding the anomaly. For example, in an ultrasonic inspection procedure, the amplitude of the response from an anomaly within a structure may be used to discriminate the response from the grain structure (noise) surrounding the anomaly as shown in Figure7-1. If the ultrasonic procedure (measurement) is applied repetitively to the same anomaly, a distribution of responses to both the anomaly and the surrounding material (grain structure) will be obtained as shown schematically in Figure 7-2. The measured response distribution reflects the variance in the NDE measurement process and is typical of that obtained for any measurement process. The response from the surrounding material constitutes the baseline level for use in discrimination of responses from internal anomalies. The baseline response may be termed "noise" (far different from electronic noise that is applied to the measurement instruments) and both the discrimination capability (anomaly detection) and anomaly sizing (quantification) capabilities for the NDE procedure are dependent on the relative amplitudes and the rate of change of the anomaly response with increasing anomaly size (slope). For purpose of discussion, the signal (plus noise) response will be referred to as the **signal** and the baseline response from the surrounding material will be referred to as **noise.**

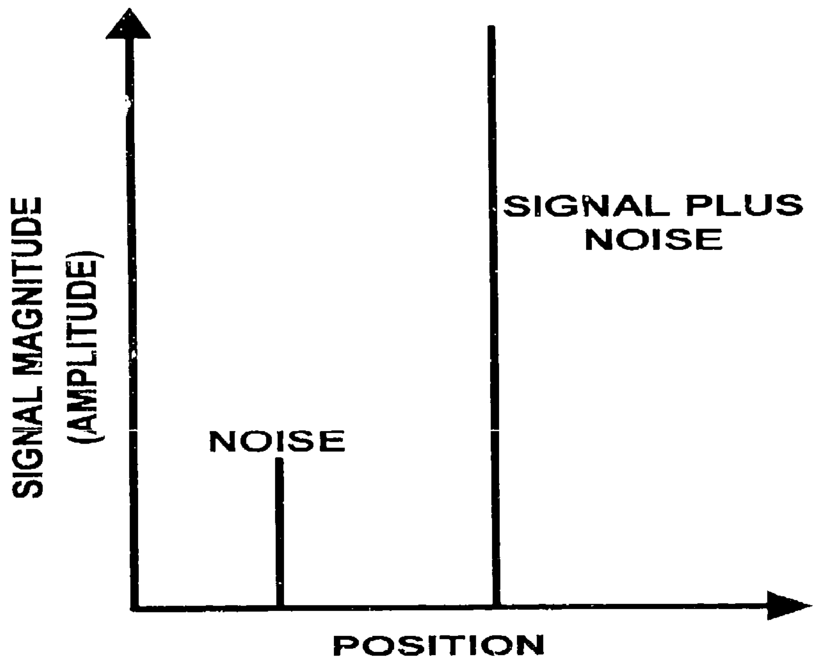


FIGURE 7-1 SIGNAL RESPONSES FOR A SINGLE ANOMALY MEASUREMENT

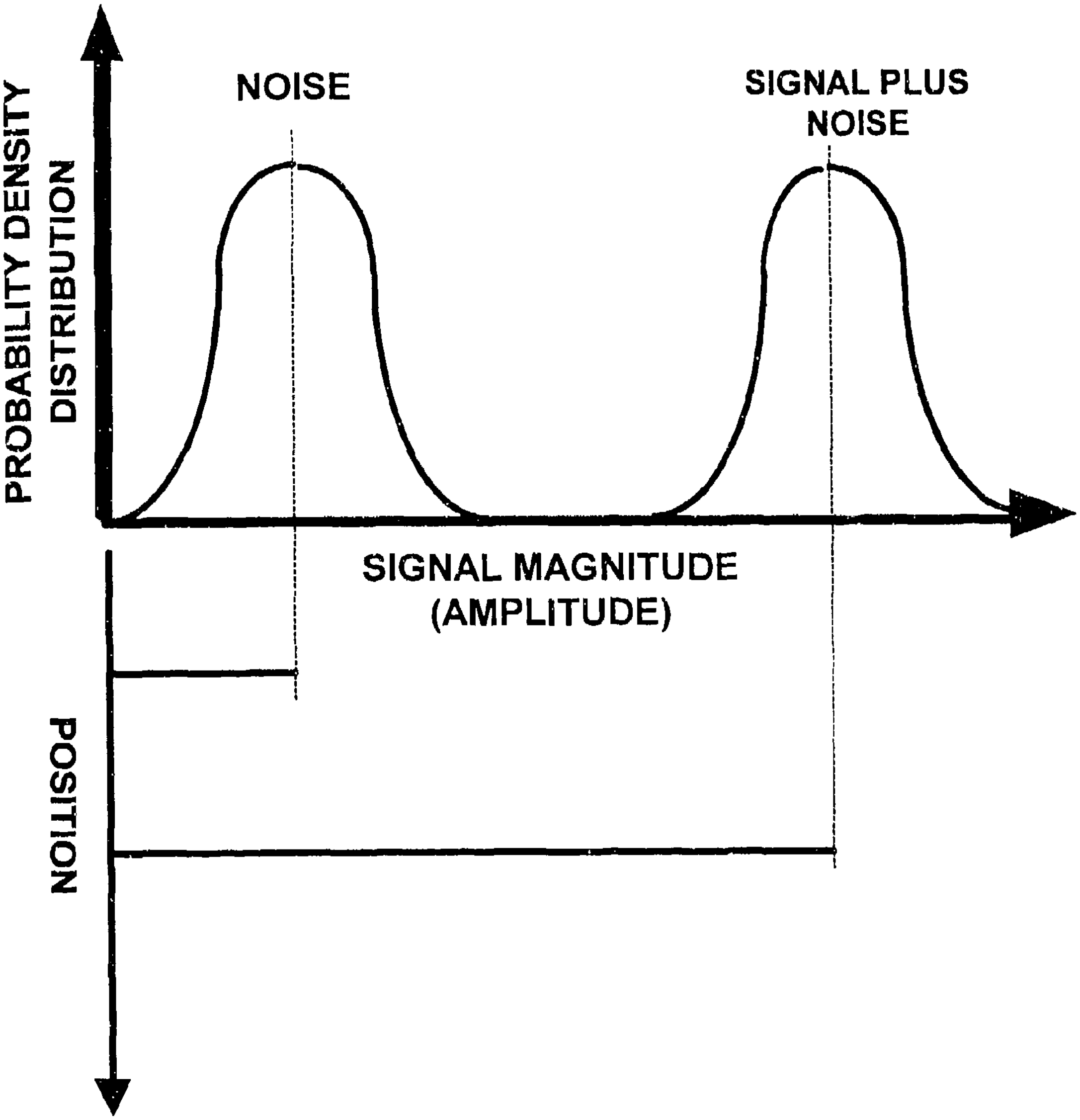


FIGURE 7 -2 SIGNAL (PLUS NOISE) AND NOISE RESPONSE DISTRIBUTIONS

The considerable flaw to flaw variance and variance in signal response to flaws of equal size causes increased spread in the probability density distribution of the signal (plus noise) response. If a threshold decision (amplitude) level is applied to the responses shown in Figure 7-2, clear flaw discrimination (detection) can be achieved as shown in Figure 7-3. If the same threshold decision level (acceptance criteria) is applied to a set of flaws of a smaller size (as shown in Figure 7-4), clear discrimination cannot be accomplished.

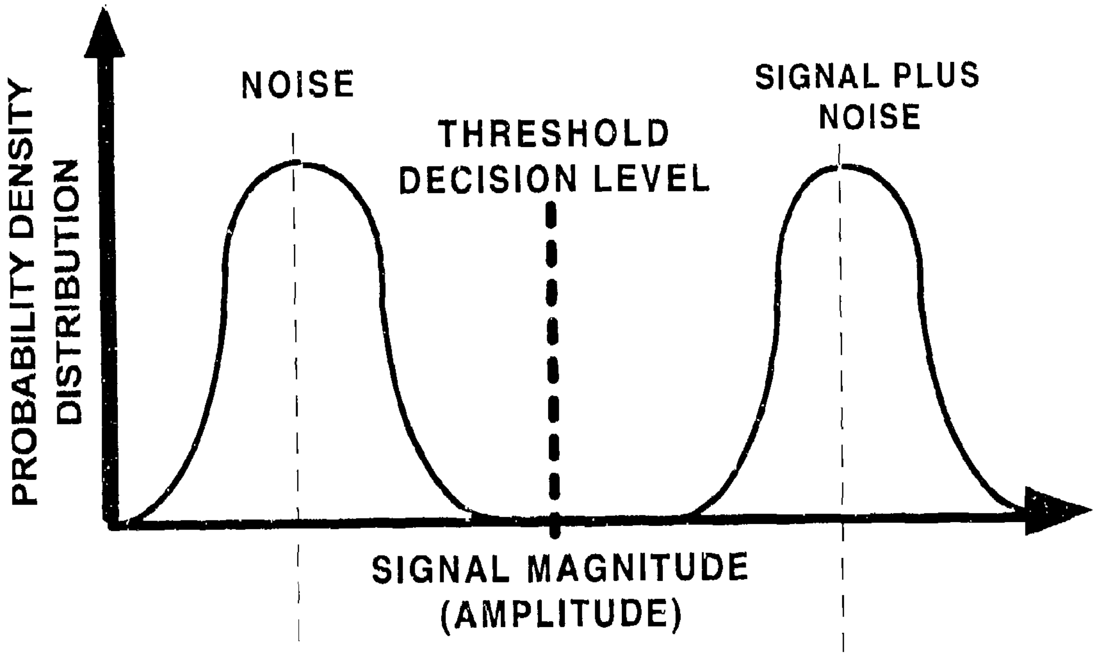


FIGURE 7-3 FLAW DETECTION AT A THRESHOLD SIGNAL LEVEL

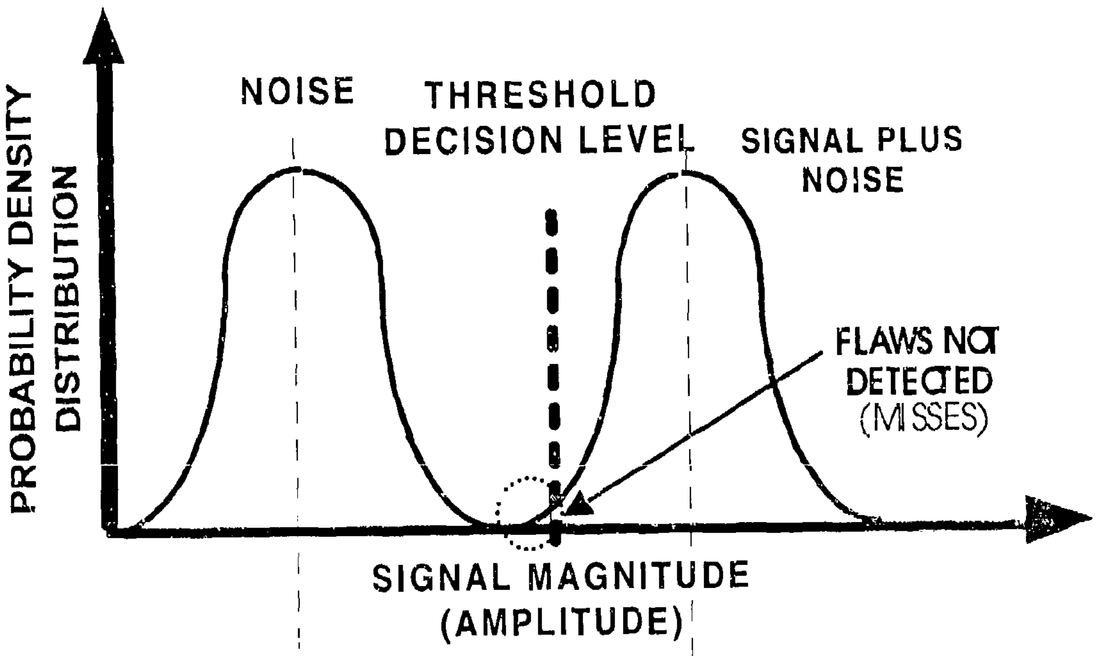


FIGURE 7-4 FAILURE TO DETECT SMALLER FLAWS AT THE SAME THRESHOLD SIGNAL LEVEL

In the example shown, the threshold decision level could be adjusted to a lower signal magnitude to produce detection. As the signal magnitude is adjusted downward to achieve detection, a slight increase in the noise level will result in a **false call**. As the flaw size decreases, the noise and signal (plus noise) responses will overlap. In such cases, a downward adjustment in the threshold decision level (to detect all flaws) will result in an increase in **false calls**. Figure 7-5 shows an example where the threshold decision level (acceptance criteria) has been adjusted to a level where a significant number of **false calls** will occur. In this example, a slight change in flaw signal distribution will also result in failure to detect a flaw. The NDE procedure is not robust and is not subject to qualification or certification for purposes of primary discrimination. The procedure may, however, be useful as a prescreening tool, if it is followed by another procedure that provides discrimination of the residuals; for example, a neural network detection process may be structured to provide discrimination at a high false call rate, but may be a useful in-line tool if other features are used for purposes of discrimination after the anomaly or variance is identified..

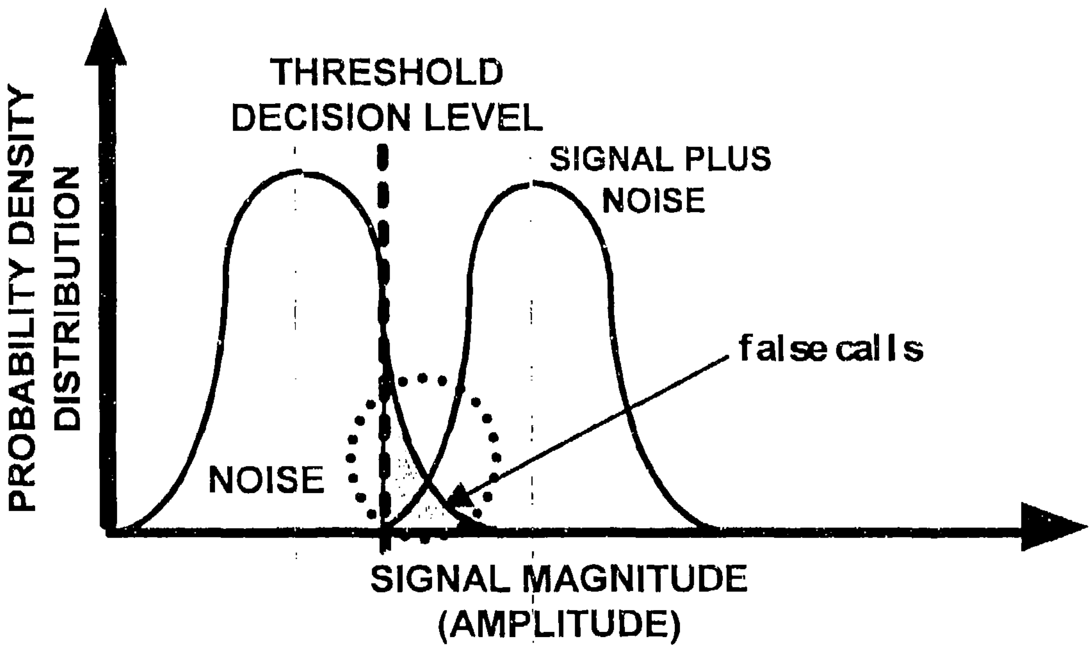


FIGURE 7-5 THRESHOLD DECISION LEVEL RESULTS IN FALSE CALLS

7.9 ACCEPT / REJECT DECISIONS FROM NDE PROCESSES

It is clear that Accept /Reject decisions resulting from the application of an NDE procedure may result in both detection failures **(MISSES)** and false position detection **(FALSE CALLS)** when the NDE procedure is operated near the limit of discrimination as shown in Figure 7-5. Theory and analysis methodologies were developed during World War II to predict the performance of radar operators in aircraft detection. The NDE discrimination / detection task is similar in nature and the same principles may be applied. From decision theory, if we assume a background signal response distribution (noise), a signal (plus noise) distribution, and a threshold decision level (acceptance criteria) as shown in Figure 7-6, it is clear that the output will be a combination of **ACCEPT, REJECT, MISSES, AND FALSE CALLS**.

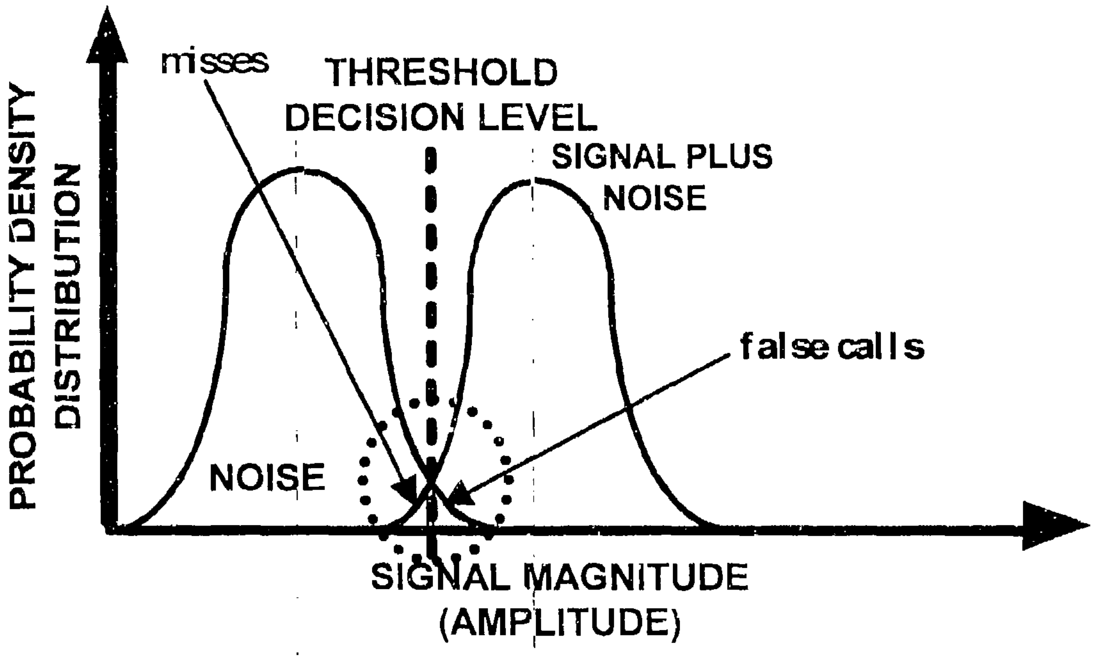


FIGURE 7-6 DECISIONS FROM SIGNAL RESPONSES AT LOW DISCRIMINATION LEVELS

The result of decisions from signal responses at low discrimination levels may be analyzed as a problem in conditional probability. Figure 7-7 is a convenient aid in visualizing a problem in conditional probability (as contrasted to joint probability - BLACK / WHITE).

NDE SIGNAL (Flaw Response)	STIMULI (Flaw Presence) POS a	STIMULI (Flaw Presence) NEG n
POS A	M(Aa) True Positive (T.P) (Flaw/Flaw) P(A,a) (NO ERROR)	M(An) False Positive (F.P.) (Flaw / No Flaw) P(A,n) (TYPE II ERROR)
NEG N	M(Na) False Negative (F.N.) (No Flaw / Flaw) P(N,a) (TYPE I ERROR)	M(Nn) True Negative (T.N.) (No Flaw / No Flaw) P(N,n) (NO ERROR)

FIGURE 7-7 CONDITIONAL PROBABILITY IN FLAW DETECTION

The outcome of the NDE procedure and decision may be:

TRUE POSITIVE (T.P.),
where M(Aa) is the total number of T.P. calls;
and P(A,a) or P(T.P.) is the probability of T.P. calls.
(Flaw Found when a Flaw is Present)
(NO ERROR CONDITION-REJECT DECISION) - **CORRECT REJECT**

FALSE POSITIVE (F.P.),
where M(An) is the total number of F.P. calls;
and P(A,n) or P(F.P.) is the probability of F.P. calls.
(Flaw Found when no Flaw is Present)
(TYPE II ERROR CONDITION - REJECT DECISION) - **FALSE CALL**

FALSE NEGATIVE (F.N.),
where M(Na) is the total number of F.N. calls;
and P(N,a) or P(F.N.) is the probability of F.N. calls.
(No Flaw Found when a Flaw is Present)
(TYPE I ERROR CONDITION - ACCEPT DECISION) - **MISS**

TRUE NEGATIVE (T.N.),
where M(Nn) is the total number of T.N. calls;
and P(N,n) or P(T.N.) is the probability of T.N. calls.
(No Flaw Found when no Flaw is Present)
(NO ERROR CONDITION - ACCEPT DECISION) - **CORRECT ACCEPT**

Interdependence of the matrix quantities is denoted by:

T.P. + F.N. = Total opportunities for positive calls.
F.P. + T.N. = Total opportunities for negative calls.

Therefore, only two independent probabilities need be considered in alternate inspection / decision tasks.

THE **SPECIFICITY** of an NDE procedure or the
PROBABILITY OF DETECTION (POD) of flaws may be expressed as:

$$\textbf{POD} = \frac{\text{T.P.}}{\text{T.P.} + \text{F.N.}} \quad \text{or} \quad \frac{\text{Total Number of Positive Calls (REJECTS)}}{\text{Total Number of Opportunities for Rejection}}$$

In like manner, the **NONSPECIFITY** of an NDE procedure or the
PROBABILITY OF FALSE ALARMS (FALSE CALLS) may be expressed as:

$$\textbf{POFA} = \frac{\text{F.P.}}{\text{T.N.} + \text{F.P.}} \quad \text{or} \quad \frac{\text{Total Number of False Positive (FALSE CALLS)}}{\text{Total Number of Opportunities for Acceptance}}$$

Application of the method requires the use of flawed test objects and assumes that all flaws are of equal size and that the variance in flaw response distribution is due solely to the measurement process. Confidence limits for the respective probabilities may be calculated from the data sample size used in the test case.

In practical applications, the NDE process characteristic that is of primary interest is the probability of detection (POD). The acceptability of a false call rate (POFA) will be dependent on the consequence of a false call for a specific application. If false calls require significant efforts for resolution, a low level of false calls will be required. If an economical and efficient secondary method is used to resolve false calls, acceptance may become part of end to end production process requirements.

7.10 FLAW RESPONSE VARIANCE IN NDE PROCEDURE APPLICATIONS

All flaws of equal size do not respond equally when an NDE procedure is applied. The physical nature of flaw initiation and growth vary considerably with the origin of the flaw (initiation source), with the material type involved, with the load history (flaw growth spectrum) on the test object, with the environment (corrosion) and with the load levels immediately prior to inspection (NDE procedure application). Crack opening and crack closure effects have been studied extensively in materials fatigue and fracture properties measurements. Crack closure has a dominant effect on crack detectability by X-ray, liquid penetrant and by ultrasonic inspection methods. Crack closure has lesser effects on magnetic and eddy current methods.

In production applications of NDE procedures, it is necessary to consider the flaw to flaw variance and the prior load history on the test object. Flaw closure effects on NDE processes are not linear and vary with flaw size. Most probability of detection (NDE) demonstration studies are therefore conducted with anomalies (cracks) that are thought to be representative of a "worst case" condition for flaw detection and therefore provide a (unquantified) margin for detection of flaws in the target population. Flaw to flaw variance in the qualification test objects is inherent in the variance in NDE procedure output and therefore is inherent in the resultant probability of detection data and curves. Documentation of the initiation, growth and load history of flaws used in POD demonstrations is a necessary requirement in reporting and for general use of the POD data.

7.11 NDE MARGINS IN PROCESS CONTROL AND USE OF NDE DECISIONS

The final result of application of an NDE process is widely held to be an absolute (black or white) decision. The perception that "it has no flaws because it passed X-ray" is inaccurate as is evident by the discussion of signal (data) / decision outputs in prior sections. All measurements are subject to variance in the measurement process and the decisions made on the basis of a measurement are subject to variance that is reflected by the fidelity and precision of the measurement. In most cases, sufficient margin is provided to make no difference in the decision process. An example might be the road mileage from Denver to San Antonio which is listed and rounded off to the nearest mile. The precision of such reported measurement is of little concern if the decision to be made is the number of travel days to allow. A wide margin in use of this measurement is inherent to the decision process. The precision of the reported measurement would, however, be of concern if the decision to be made is for purpose of survey or land ownership. The narrowest margin possible is desired in the case of the survey decision. The margin limit is in turn dependent on the variances and hence the precision uncertainties inherent in the measurement process. In like manner, inherent variances in the NDE method or NDE procedure must be taken into account in both the decision

processes and in the use of the resultant decision information (data). Risks in accepting a manual liquid penetrant inspection for detection of a small critical flaw are greater than the risks in accepting an automated eddy current procedure for the same task. The risks assumed are inherent to the variances in NDE procedure output (measurement precision) and the threshold decision level (acceptance criteria) applied.

Margins in use of NDE data are commonly used in life cycle management of engineering systems. For example, in life-cycle analysis in aircraft maintenance, it is common practice to provide for two or more NDE inspection opportunities for detection of "critical cracks". This does not reduce the requirement for rigor in demonstrating NDE capabilities for detection at the "critical crack length". As engineering technology advances, requirements for predicting and measuring NDE procedure variances are anticipated to be included in requirements for demonstrating NDE capabilities. The added requirements do not reduce the general applicability of NDE procedures or change the requirements for general applications where the result of imprecision in the NDE procedure is of little consequence in meeting the design, process control, or life-cycle management objectives. Application of a margin for NDE acceptance is an element of the robustness of the design, the reliability of the design and the confidence level associated with the design reliability.

7.12 LESSONS LEARNED IN APPLICATION OF POD METHODS

Lessons learned by application of POD methods to NDE procedure characterization include the following:

- NDE capabilities are rarely at the levels assumed by deterministic process management;
- Human factors in NDE are important, but are most often not the weak link in NDE procedure application;
- NDE capabilities are rarely at the level assumed by use of a "calibration" artifact of a fixed size (Note: Calibration artifacts ("standards") are extremely important in establishing a baseline set-point and a linearity response check for instrumented NDE methods);
- Calibration artifacts are a primary source of variance in the reproducibility and repeatability of NDE procedures that are conducted at different locations;
- "Standard" NDE procedures should be periodically assessed to assure that the procedure is producing the desired result (Note: The 29/29 point estimate test is a rapid method of providing assurance of basic and continuing NDE procedure performance);
- Not all NDE procedures require characterization / quantification. The use of the procedure may reduce the need for characterization. (Note: The cost of controlled process application is the same as that of process application ceremonies); and
- The POD method is integral to meeting critical DAMAGE TOLERANCE REQUIREMENTS.

7.13 SUMMARY

Nondestructive evaluation (NDE) processes have evolved as essential tools in the production, acceptance, life-cycle operations and maintenance of modern engineering materials, components, structures and systems. In many applications, a traditional "best effort" or workmanship confidence in NDE procedure application is adequate to provide the required level of discrimination and confidence in "fitness for purpose" of the test object. As demands for NDE procedures have increased, new methods and increased precision in application have been realized, and reliance on NDE procedure application has increased to produce increasing efficiencies in engineering designs and to add confidence in continuing fitness for purpose of aging system. While the basic principles of NDE processes are simple in concept as described in previous sections of this chapter, precision and confidence level in application require in-depth understanding and control of NDE process parameters. Quantification of NDE procedure capabilities is a complex process and a measure of the maturity of NDE technology. Excellence in NDE procedure development, qualification, application and management are essential to capable and reliable NDE process application. This data book is dedicated to the goal of "Excellence in NDE engineering and NDE process application".

8. DATA BOOK PRESENTATION

8.0 FORMAT OF THE APPENDICES

Reference POD data are organized and presented by NDE method in Appendices (A-F) of this data book. A documentation page precedes each data-set and provides a condensed description of the test object, test artifacts, NDE procedure, critical characteristics and parameters, and results summary. The POD curves for varying test object, test artifact and data collection conditions follow the documentation page. Each POD curve is identified with the documentation page and the original reference source for data reporting in the footer. For example, **MT - 02 (4),** relates the POD curve to the documentation page with the same title and identifies the source of the data as Appendices, Reference 4.

POD data are presented as a function of crack length, crack depth, and crack depth-to-thickness ratio for selected data sets. For purposes of consistency, the same crack size range and POD analysis model (Log-logistic) have been used for all plots. For simplicity in presentation and comparison, the lower bound 95% confidence curve is not shown. Deletion of the lower 95% confidence bound in the POD plots is intended to emphasize the need for the user to independently validate NDE procedures that are used in critical designs.

All POD plots in these initial data sets are based on "hit / miss" data. The fidelity of NDE procedure documentation and details of the "design of experiment" vary with the data source and are presented with the information provided in the original reference. A parameter is listed as "not documented" or "N.A. - not applicable" when such information is not found in the original reference

8.1 REFERENCES TO DATA SETS:

1 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, The Detection of Fatigue Cracks by Nondestructive Testing Methods, NASA CR-2369 February 1974.

2 Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, The Detection of Tightly Closed Flaws by Nondestructive Testing (NDT) Methods in Steel and Titanium, NASA CR-151098, September 1976.

3 Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen, The Detection of Tightly Closed Flaws by Nondestructive Testing (NDT) Methods, NASA CR-144639, October 1975.

4 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks, LTR-ST-1961, Institute for Aerospace Research, National Research Council Canada, February 1994.

5 Spencer, Floyd and Donald Schurman, Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment, DOT/FAA/CT-92/12,III, May 1995.

6 Christner, Brent K. and Ward D. Rummel, NDE Detectability of Fatigue Type Cracks in High Strength Alloys, NASA Contract NAS8-34425, National Aeronautics and Space Administration, Marshall Space Flight Center, July 1983.

7 Forsyth, D.S. and A. Fahr, The Sensitivity and Reliability of NDI Techniques for Gas Turbine Component Inspection and Life Prediction, LTR-ST-2055, Institute for Aerospace Research, National Research Council Canada, August 1996.

INTRODUCTION TO THE APPENDICES

The information contained herein is in the same configuration as the original 1st edition, published in 1996, and 2nd edition published in 1997, with pages added to provide upgrade to the third edition. A master index to the Appendices is provided which includes both the original 1st edition data as well as the added 2nd edition and 3rd edition data. The indexing nomenclature was changed for the 2nd edition data to provide files names for the electronic version of The Data Book which is available on CD-ROM. Therefore, in the Index to the Appendices, the 1st edition data are referenced by both the original identification (ID) numbers as well as the electronic file names, whereas the 2nd and 3rd edition data are referenced only by the electronic file names.

The CD version of the Data Book is in Microsoft Windows 95/Word 6.0/Excel, 7.0 formats. Individual Appendix data files are formatted and stored in Microsoft Excel 7.0. The master Index to the Appendices is organized and formatted in both Microsoft Word 6.0 and Microsoft Excel 7.0. The search feature of Word 6.0 can be used for reference while in the Microsoft Word 6.0 application, while the Excel index can be used for quick reference while using the Excel 7.0 application in the data or graphical files modes.

Users are cautioned that the information and data presented is specific to the original application and is provided for purposes of reference only. Data are intended to provide a reference source of what can be accomplished by a specific NDE procedure and may thus be used as an NDE engineering reference. The user is responsible for demonstration of capabilities of a specific procedure in each critical NDE application and for transferability of data to a specific application.

INDEX

TO THE

APPENDICES

(Provided in "Microsoft Word 6.0"®
for
the CD Version)

FILE	ID	TEST SPECIMENS	OPERATOR
A-ET1			
A1000(1L	**ET-01(1)L**	**Eddy current hand scan of Aluminum flat panels by crack length**	
A1001AL	ETAAA01L-A	As Machined	Operator A
A1001BL	ETAAA01L-B	As Machined	Operator B
A1001CL	ETAAA01L-C	As Machined	Operator C
A1002AL	ETAAA02L-A	After Etch	Operator A
A1002BL	ETAAA02L-B	After Etch	Operator B
A1002CL	ETAAA02L-C	After Etch	Operator C
A1003AL	ETAAA03L-A	After Proof	Operator A
A1003BL	ETAAA03L-B	After Proof	Operator B
A1003CL	ETAAA03L-C	After Proof	Operator C
A-ET2			
A2000(1L	**ET-02(1)L**	**Eddy current hand scan of Aluminum flat panels by crack length**	
A2002AL	ETAAB02L-A	After Etch	Operator A
A2002BL	ETAAB02L-B	After Etch	Operator B
A2002CL	ETAAB02L-C	After Etch	Operator C
A-ET3			
A3000(2L	**ET-03(2)AL**	**Eddy current hand scan of Titanium flat panels by crack length**	
A3001AL	ETAA01L-A	As Machined	Operator A
A3001BL	ETAA01L-B	As Machined	Operator B
A3001CL	ETAA01L-C	As Machined	Operator C
A3003AL	ETAA03L-A	After Proof	Operator A
A3003BL	ETAA03L-B	After Proof	Operator B
A3003CL	ETAA03L-C	After Proof	Operator C
A-ET4			
A4000(4L	**ET-04(4)**	**Eddy current inspection of Sixth stage, J85 compressor disks by crack length**	
A40011	ETCAA01L-I	Bolt Holes	Laboratory I
A40013	ETCAA01L-III	Bolt Holes	Laboratory III
A40014	ETCAA01L-IV	Bolt Holes	Laboratory IV
A40015	ETCAA01L-V	Bolt Holes	Laboratory V
A40016	ETCAA01L-VI	Bolt Holes	Laboratory VI

FILE	ID	TEST SPECIMENS	OPERATOR
A-ET5			
A5000(4L	**ET-05(4)**	**Eddy current inspection of Fourth stage, J85 spacers by crack length**	
A50011	ETCAB01L-I	Bolt Holes	Laboratory I
A50013	ETCAB01L-III	Bolt Holes	Laboratory III
A50014	ETCAB01L-IV	Bolt Holes	Laboratory IV
A50015	ETCAB01L-V	Bolt Holes	Laboratory V
A50016	ETCAB01L-VI	Bolt Holes	Laboratory VI
A-ET6			
A6000(5A	**ET-06(5)A**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001A	ETAAHFA-1	Unpainted, Template 200kHz	Facility A, Operator 1
A6001AR	ETAAHFA-1R	Unpainted, Template 200kHz	Facility A, Operator 1 Repeat
A6002A	ETAAHFA-2	Unpainted, Template 200kHz	Facility A, Operator 2
A6003A	ETAAHFA-3	Unpainted, Template 200kHz	Facility A, Operator 3
A6004A	ETAAHFA-4	Unpainted, Template 200kHz	Facility A, Operator 4
A6000(5B	**ET-06(5)B**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001B	ETAAHFB-1	Painted, Sliding Probe, 30kHz	Facility B, Operator 1
A6002B	ETAAHFB-2	Painted, Sliding Probe, 30kHz	Facility B, Operator 2
A6003B	ETAAHFB-3	Painted, Sliding Probe, 30kHz	Facility B, Operator 3
A6004B	ETAAHFB-4	Painted, Sliding Probe, 30kHz	Facility B, Operator 4
A6004BR	ETAAHFB-4R	Painted, Sliding Probe, 30kHz	Facility B, Operator 4 Repeat
A6000(5C	**ET-06(5)C**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001C	ETAAHFC-1	Unpainted, Sliding Probe, 38kHz	Facility C, Operator 1

FILE	ID	TEST SPECIMENS	OPERATOR
A6002C	ETAAHFC-2	Unpainted, Sliding Probe, 38kHz	Facility C, Operator 2
A6003C	ETAAHFC-3	Unpainted, Sliding Probe, 38kHz	Facility C, Operator 3
A6004C	ETAAHFC-4	Unpainted, Sliding Probe, 38kHz	Facility C, Operator 4
A6004CR	ETAAHFC-4R	Unpainted, Sliding Probe, 38kHz	Facility C, Operator 4 Repeat
A6000(5D	**ET-06(5)D**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001D	ETAAHFD-1	Unpainted, Template 200kHz	Facility D, Operator 1
A6002D	ETAAHFD-2	Unpainted, Template 200kHz	Facility D, Operator 2
A6002DR	ETAAHFD-2R	Unpainted, Template 200kHz	Facility D, Operator 2 Repeat
A6003D	ETAAHFD-3	Unpainted, Template 200kHz	Facility D, Operator 3
A6004D	ETAAHFD-4	Unpainted, Template 200kHz	Facility D, Operator 4
A6000(5E	**ET-06(5)E**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001E	ETAAHFE-1	Painted, Template, 100kHz	Facility E, Operator 1
A6002E	ETAAHFE-2	Painted, Template, 100kHz	Facility E, Operator 2
A6002ER	ETAAHFE-2R	Painted, Template, 100kHz	Facility E, Operator 2 Repeat
A6003E	ETAAHFE-3	Painted, Template, 100kHz	Facility E, Operator 3
A6004E	ETAAHFE-4	Painted, Template, 100kHz	Facility E, Operator 4
A6000(5F	**ET-06(5)F**	**Eddy current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001F	ETAAHFF-1	Unpainted, Sliding Probe, 26kHz, MIZ-20	Facility F, Operator 1
A6002F	ETAAHFF-2	Unpainted, Sliding Probe, 26kHz, MIZ-20	Facility F, Operator 2
A6003F	ETAAHFF-3	Unpainted, Sliding Probe, 26kHz, MIZ-20	Facility F, Operator 3
A6004F	ETAAHFF-4	Unpainted, Sliding Probe, 26kHz, MIZ-20	Facility F, Operator 4

FILE	ID	TEST SPECIMENS	OPERATOR
A6004FR	ETAAHFF-4R	Unpainted, Sliding Probe, 26kHz, MIZ-20	Facility F, Operator 4 Repeat
A6000(5G	**ET-06(5)G**	**Eddy Current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
G6001G	ETAAHFG-1	Painted, Template 200kHz	Facility G, Operator 1
G6001GR	ETAAHFG-1R	Painted, Template 200kHz	Facility G, Operator 1 Repeat
G6002G	ETAAHFG-2	Painted, Template 200kHz	Facility G, Operator 2
G6003G	ETAAHFG-3	Painted, Template 200kHz	Facility G, Operator 3
G6004G	ETAAHFG-4	Painted, Template 200kHz	Facility G, Operator 4
A6000(5H	**ET-06(5)H**	**Eddy Current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001H	ETAAHFH-1	Painted, Sliding Probe, 24kHz	Facility H, Operator 1
A6002H	ETAAHFH-2	Painted, Sliding Probe, 24kHz	Facility H, Operator 2
A6002HR	ETAAHFH-2R	Painted, Sliding Probe, 24kHz	Facility H, Operator 2, Repeat
A6003H	ETAAHFH-3	Painted, Sliding Probe, 24kHz	Facility H, Operator 3
A6004H	ETAAHFH-4	Painted, Sliding Probe, 24kHz	Facility H, Operator 4
A6000(5J	**ET-06(5)J**	**Eddy Current, hand scan of Aluminum Aircraft lap splice joints by crack length**	
A6001J	ETAAHFJ-1	Painted, Sliding Probe, 250kHz, NDT-19	Facility J, Operator 1
A6001JR	ETAAHFJ-1R	Painted, Sliding Probe, 250kHz, NDT-19	Facility J, Operator 1 Repeat
A6002J	ETAAHFJ-2	Painted, Sliding Probe, 250kHz, MIZ-20	Facility J, Operator 2
A6003J	ETAAHFJ-3	Painted, Sliding Probe, 250kHz,MIZ-20	Facility J, Operator 3
A6004J	ETAAHFJ-4	Painted, 460kHz, rotating probe	Facility J, Operator 4

FILE	ID	TEST SPECIMENS	OPERATOR
A-ET7			
A7000(2)L		**Eddy current inspection of 4340 steel flat plate panels, by crack length**	
A7001AL		As Machined.	Operator A
A7001BL		As Machined	Operator B
A7001CL		As Machined	Operator C
A7003AL		Etched and Proof Loaded	Operator A
A7003BL		Etched and Proof Loaded	Operator B
A7003CL		Etched and Proof Loaded	Operator C
A-ET8			
A8000(7)		**Eddy current inspection of bolt holes in J85, seventh stage compressor disks, by crack length**	
A8001L		Bolt Holes	Organization A
A8002L		Bolt Holes	Organization B at 0.5 threshold.
A8003L		Bolt Holes	Organization B at 0.8 threshold.
A8004L		Bolt Holes	Organization A with automatic pattern recognition.
A8005L		Bolt Holes	Organization A
A8006L		Bolt Holes	Organization C
A-ET9			
A9000(3)L,D		**Eddy Current Scan of Aircraft Stiffened Stringer Panels**	
A9001(3)L		As Machined	By Length
A9002(3)L		After Etch	
A9003(3)L		After Riveting to a Substrate Panel	
A9001(3)D		As Machined	By Depth
A9002(3)D		After Etch	
A9003(3)D		After Riveting to a Substrate Panel	

FILE	ID	TEST SPECIMENS	OPERATOR
A-ETA			
AA000(3)L		**Eddy Current Inspection of Lack of Penetration Defects in Welds**	
AA001(3)L		As Welded and Scarfed	Combined - 3 Operators
AA002(3)L		After Etch	
AA003(3)L		After Proof Loading	
A-ETB			
AB000(3)L		**Eddy Current Inspection of Longitudinal Fatigue Cracks in Welds with Crowns**	
AB001(3)L		As Welded and Scarfed	Combined - 3 Operators
AB002(3)L		After Etch	
AB003(3)L		After Proof Loading	
A-ETC			
AC000(3)L		**Eddy Current Inspection of Transverse Fatigue Cracks in Welds with Crowns**	
AC001(3)L		As Welded and Scarfed	Combined - 3 Operators
AC002(3)L		After Etch	
AC003(3)L		After Proof Loading	
A-ETD			
AD000(3)L		**Eddy Current Inspection of Longitudinal Fatigue Cracks in Flush Welds**	
AD001(3)L		As Welded and Scarfed	Combined - 3 Operators
AD002(3)L		After Etch	
AD003(3)L		After Proof Loading	
A-ETE			
AE000(3)L		**Eddy Current Inspection of Transverse Fatigue Cracks in Flush Welds**	
AE001(3)L		As Welded and Scarfed	Combined - 3 Operators
AE002(3)L		After Etch	
AE003(3)L		After Proof Loading	

FILE	ID	TEST SPECIMENS	OPERATOR
B-MT1			
B1000(2)		**Magnetic particle inspection of 4340 steel flat panels by crack length**	
B1001AL		As machined	Operator A
B1001BL		As machined	Operator B
B1001CL		As machined	Operator C
B1003AL		After etch and proof	Operator A
B1003BL		After etch and proof	Operator B
B1003CL		After etch and proof	Operator C
B-MT2			
B2000(4)	**MT-02(4)**	**Magnetic particle inspection of J85 / sixth stage compressor disks, by crack length**	
B20011	MTCAA01L-I	Bolt Holes	Organization 1
B20012	MTCAA01L-II	Bolt Holes	Organization 2
B20013	MTCAA01L-III	Bolt Holes	Organization 3
B-MT3			
B3000(4)	**MT-03(4)**	**Magnetic particle inspection of J85 / fourth stage spacers, by crack length**	
B30011	MTCAB01L-I	Bolt Holes	Organization 1
B30012	MTCAB01L-II	Bolt Holes	Organization 2
B-MT4			
A4000(7)		**Magnetic particle inspection of J-85, seventh stage compressor disks, by crack length**	
A4001(7)		J-85, seventh stage compressor disks.	Organization D

FILE	ID	TEST SPECIMENS	OPERATOR
C-PT1			
C1000(1L	**PT-01(1L**	**Fluorescent penetrant on aluminum flat plates, 0.060" and 0.220" thicknesses, by crack length**	
C1001AL	PTAAA01L-A	As Machined	Operator A
C1001BL	PTAAA01L-B	As Machined	Operator B
C1001CL	PTAAA01L-C	As Machined	Operator C
C1002AL	PTAAA02L-A	After Etch	Operator A
C1002BL	PTAAA02L-B	After Etch	Operator B
C1002CL	PTAAA02L-C	After Etch	Operator C
C1003AL	PTAAA03L-A	After Proof	Operator A
C1003BL	PTAAA03L-B	After Proof	Operator B
C1003CL	PTAAA03L-C	After Proof	Operator C
C-PT2			
C2000(1L	**PT-02(1L**	**Fluorescent penetrant on aluminum flat plates, 0.085" and 0.220" thicknesses, by crack length**	
C2002AL	PTAAB02L-A	After Etch	Operator A
C2002BL	PTAAB02L-B	After Etch	Operator B
C2002CL	PTAAB02L-C	After Etch	Operator C
C-PT3			
C3000(2L	**PT-03(2LAL**	**Fluorescent penetrant on titanium flat plates, 0.065" and 0.225" thickness, by crack length**	
C3001AL	PTAA01L-A	As Machined	Operator A
C3001BL	PTAA01L-B	As Machined	Operator B
C3001CL	PTAA01L-C	As Machined	Operator C
C3002AL	PTAA02L-A	After Etch	Operator A
C3002BL	PTAA02L-B	After Etch	Operator B
C3002CL	PTAA02L-C	After Etch	Operator C
C3003AL	PTAA03L-A	After Proof	Operator A
C3003BL	PTAA03L-B	After Proof	Operator B
C3003CL	PTAA03L-C	After Proof	Operator C

APPENDIX C: FLUORESCENT PENTRANT

FILE	ID	TEST SPECIMENS	OPERATOR
C-PT4			
C4000(4L	**PT-04(4L**	**Fluorescent penetrant of J85 / sixth stage compressor disks, by crack length**	
C400011	PTCAA01L-I	Bolt Holes	Organization 1
C400012	PTCAA01L-II	Bolt Holes	Organization 2
C400013	PTCAA01L-III	Bolt Holes	Organization 3
C400014	PTCAA01L-IV	Bolt Holes	Organization 4
C-PT5			
C5000(4L	**PT-05(4L**	**Fluorescent penetrant of J85 / fourth stage spacers, by crack length**	
C500011	PTCAB01L-I	Bolt Holes	Organization 1
C500012	PTCAB01L-II	Bolt Holes	Organization 2
C500014	PTCAB01L-IV	Bolt Holes	Organization 4
C500016	PTCAB01L-VI	Bolt Holes	Organization 6
C-PT6			
C6000(2)		**Fluorescent penetrant on 4340 steel flat plates, by crack length**	
C6001AL		As Machined	Operator A
C6001BL		As Machined	Operator B
C6001CL		As Machined	Operator C
C6002AL		After Etch	Operator A
C6002BL		After Etch	Operator B
C6002CL		After Etch	Operator C
C6003AL		After Etch and Proof	Operator A
C6003BL		After Etch and Proof	Operator B
C6003CL		After Etch and Proof	Operator C
C-PT7			
C7000(7L		**Fluorescent penetrant of J85 / Seventh stage compressor disks, by crack length**	
C7001L		Bolt Holes	Organization A
C7002L		Bolt Holes	Organization B
C7003L		Bolt Holes	Organization C

APPENDIX C: FLUORESCENT PENTRANT

FILE	ID	TEST SPECIMENS	OPERATOR
C-PT8			
C8000(3)L,D		**Fluorescent Penetrant Inspection of Aircraft Stiffened Stringer Panels**	Combined - 3 Operators
C8001(3)L		As Machined	By Length
C8002(3)L		After Etch	
C8003(3)L		After Riveting to a Substrate Panel	
C8001(3)D		As Machined	By Depth
C8002(3)D		After Etch	
C8003(3)D		After Riveting to a Substrate Panel	
C-PT9			
C9000(3)L		**Fluorescent Penetrant Inspection of Lack of Penetration (LOP) Defects in Aluminum Alloy GTA Welds**	
C9001(3)L		As Welded	Combined - 3 Operators
C9002(3)L		After Scarfing	
C9003(3)L		After Etch	
C9004(3)L		After Proof Loading	
C-PTA			
CA000(3)L		**Fluorescent Penetrant Inspection of Longitudinal Fatigue Cracks in Welds with Crowns**	
CA001(3)L		As Welded and Scarfed	Combined - 3 Operators
CA002(3)L		After Etch	
CA003(3)L		After Proof Loading	
C-PTB			
CB000(3)L		**Fluorescent Penetrant Insection of Transverse Fatigue Cracks in Welds with Crowns**	
CB001(3)L		As Welded and Scarfed	Combined - 3 Operators
CB002(3)L		After Etch	
CB003(3)L		After Proof Loading	

FILE	ID	TEST SPECIMENS	OPERATOR
C-PTC			
CC000(3)L		**Fluorescent Penetrant Inspection of Longitudinal Fatigue Cracks in Flush Welds**	
CC001(3)L		As Welded and Scarfed	Combined - 3 Operators
CC002(3)L		After Etch	
CC003(3)L		After Proof Loading	
C-PTD			
CD000(3)L		**Fluorescent Penetrant Inspection of Transverse Fatigue Cracks in Flush Welds**	
CD001(3)L		As Welded and Scarfed	Combined - 3 Operators
CD002(3)L		After Etch	
CD003(3)L		After Proof Loading	
C-PTE			
CE000(6)L, D		**Water Washable Fluorescent Penetrant on Haynes 188 Flat Panels**	
CE011(6)L		No Developer, by Length	Facility 1, Operator A
CE011(6)D		No Developer, by Depth	Facility 1, Operator A
CE012(6)L		CEO11(6)L, with Aqueous Developer	Facility 1, Operator A
CE012(6)D		CEO11(6)D, with Aqueous Developer	Facility 1, Operator A
CE021(6)L		No Developer, by Length	Facility 1, Operator B
CE021(6)D		No Developer, by Depth	Facility 1, Operator B
CE022(6)L		CEO11(6)L, with Aqueous Developer	Facility 1, Operator B
CE022(6)D		CEO11(6)D, with Aqueous Developer	Facility 1, Operator B
CE031(6)L		No Developer, by Length	Facility 1, Operator C
CE031(6)D		No Developer, by Depth	Facility 1, Operator C
CE032(6)L		CEO11(6)L, with Aqueous Developer	Facility 1, Operator C
CE032(6)D		CEO11(6)D, with Aqueous Developer	Facility 1, Operator C
CE041(3)L		No Developer, by Length	Facility 1, Operator H
CE041(3)D		No Developer, by Depth	Facility 1, Operator H

APPENDIX C: FLUORESCENT PENTRANT

FILE	ID	TEST SPECIMENS	OPERATOR
CE042(6)L		CEO11(6)L with Aqueous Developer	Facility 1 Operator H
CE042(6)D		CEO11(6)D with Aqueous Developer	Facility 1 Operator H
CE051(6)L		No Developer by Length	Facility 1 Operator J
CE051(6)D		No Developer by Depth	Facility 1 Operator J
CE052(6)L		CEO11(6)L with Aqueous Developer	Facility 1 Operator J
CE052(6)D		CEO11(6)D with Aqueous Developer	Facility 1 Operator J
CE061(6)L		No Developer by Length	Facility 1 Operator P
CE061(6)D		No Developer by Depth	Facility 1 Operator P
CE062(6)L		CEO11(6)L with Aqueous Developer	Facility 1 Operator P
CE062(6)D		CEO11(6)D with Aqueous Developer	Facility 1 Operator P
CE071(6)L		No Developer by Length	Facility 1 Operator R
CE071(6)D		No Developer by Depth	Facility 1 Operator R
CE072(6)L		CEO11(6)L with Aqueous Developer	Facility 1 Operator R
CE072(6)D		CEO11(6)D with Aqueous Developer	Facility 1 Operator R
CE081(6)L		400 mwatts Black Light	Facility 1. Operator G
CE081(6)D		400 mwatts Black Light	Facility 1. Operator G

FILE	ID	TEST SPECIMENS	OPERATOR
D-UT1			
D1000(1L	**UT-01(1)L**	**Ultrasonic inspection (surface wave) on aluminum flat plates, 0.060" and 0.220" thicknesses, by crack length**	
D1001AL	UTAAA01L-A	As Machined	Operator A
D1001BL	UTAAA01L-B	As Machined	Operator B
D1001CL	UTAAA01L-C	As Machined	Operator C
D1002AL	UTAAA02L-A	After Etch	Operator A
D1002BL	UTAAA02L-B	After Etch	Operator B
D1002CL	UTAAA02L-C	After Etch	Operator C
D1003AL	UTAAA03L-A	After Proof	Operator A
D1003BL	UTAAA03L-B	After Proof	Operator B
D1003CL	UTAAA03L-C	After Proof	Operator C
D1000(1)D	**UT-01(1)D**	**Ultrasonic inspection (surface wave) on aluminum flat plates, 0.060" and 0.220" thicknesses, by crack depth**	
D1001AD	UT-AAA01D-A	As Machined	Operator A
D1001BD	UT-AAA01D-B	As Machined	Operator B
D1001CD	UT-AAA01D-C	As Machined	Operator C
D1002AD	UT-AAA02D-A	After Etch	Operator A
D1002BD	UT-AAA02D-B	After Etch	Operator B
D1002CD	UT-AAA02D-C	After Etch	Operator C
D1003AD	UT-AAA03D-A	After Proof	Operator A
D1003BD	UT-AAA03D-B	After Proof	Operator B
D1003CD	UT-AAA03D-C	After Proof	Operator C
D-UT2			
D2000(1	**UT-02(1)L**	**Ultrasonic inspection (surface wave) on aluminum flat plates, 0.085" and 0.220" thicknesses, by crack length and depth**	
D2002AL	UTAAB02L-A	After Ech, By Length	Operator A
D2002BL	UTAAB02L-B	After Ech, By Length	Operator B

FILE	ID	TEST SPECIMENS	OPERATOR
D2002CL	UTAAB02L-C	After Ech, By Length	Operator C
D2002AD	UTAAB02D-A	After Ech, By Depth	Operator A
D2002BD	UTAAB02D-B	After Ech, By Depth	Operator B
D2002CD	UTAAB02D-C	After Ech, By Depth	Operator C
D-UT3			
D3000(2L	**UT-03(2)A L**	**Ultrasonic inspection (surface wave) on titanium flat plates, 0.065" and 0.225" thickness, by crack length**	
D3001AL	UTAA01L-A	As Machined	Operator A
D3001BL	UTAA01L-B	As Machined	Operator B
D3001CL	UTAA01L-C	As Machined	Operator C
D3003AL	UTAA03L-A	After Proof	Operator A
D3003BL	UTAA03L-B	After Proof	Operator B
D3003CL	UTAA03L-C	After Proof	Operator C
D-UT4			
D4000(4	**UT-04(4)**	**Ultrasonic inspection (surface wave) in J85 / sixth stage compressor disks, by crack length**	
D4004	UTCAA01LW-IV	Bolt Holes	Organization 4
D-UT5			
D5000(4	**UT-05(4)**	**Ultrasonic inspection (surface wave) in J85 / fourth stage spacers, by crack length**	
D5004	UTCAB01LW-IV	Bolt Holes	Organization 4
D-UT6			
D6000(2)		**Ultrasonic inspection (surface wave) on 4340 steel plates, by crack length.**	
D6001AL		As Machined	Operator A
D6001BL		As Machined	Operator B
D6001CL		As Machined	Operator C
D6003AL		After Proof	Operator A
D6003BL		After Proof	Operator B
D6003CL		After Proof	Operator C

FILE	ID	TEST SPECIMENS	OPERATOR
D-UT7			
D7000(7)L		**Ultrasonic inspection of J85 / seventh stage compressor disks, by crack length**	
D7001L		Bolt Holes	Organization A, Operator 1
D7002L		Bolt Holes	Organization A, Operator 2
D7003L		Bolt Holes	Organization C
D-UT8			
D8000(3)L, D		**Ultrasonic Inspection of Aircraft Stiffened Stringer Panels**	Combined - 3 Operators
D8001(3)L		As Machined	By Length
D8002(3)L		After Etch	
D8003(3)L		After Riveting to a Substrate Panel	
D8001(3)D		As Machined	By Depth
D8002(3)D		After Etch	
D8003(3)D		After Riveting to a Substrate Panel	
D-UT9			
D9000(3)L, D		**Ultrasonic Inspection of Lack of Penetration (LOP) Defects in Aluminum Alloy GTA Welds**	Combined - 3 Operators
D9001(3)L		As Welded and Scarfed	By Length
D9002(3)L		After Etch	
D9003(3)L		AfterProof Loading	
D9001(3)D		As Welded and Scarfed	By Depth
D9002(3)D		After Etch	
D9003(3)D		AfterProof Loading	
D9004(3)L		As Welded and Scarfed	By Length
D9005(3)L		After Etch	
D9006(3)L		AfterProof Loading	
D9004(3)D		As Welded and Scarfed	By Depth
D9005(3)D		After Etch	
D9006(3)D		AfterProof Loading	

APPENDIX D: ULTRASONIC INSPECTION

FILE	ID	TEST SPECIMENS	OPERATOR
D-UT9			
DA000(3)L,D		**Ultrasonic Inspection of Longitudinal Fatigue Cracks in Welds with Crowns**	Combined - 3 Operators
DA001(3)L		As Welded and Scarfed	By Length
DA002(3)L		After Etch	
DA003(3)L		AfterProof Loading	
DA001(3)D		As Welded and Scarfed	By Depth
DA002(3)D		After Etch	
DA003(3)D		AfterProof Loading	

APPENDIX E: VISUAL INSPECTION /OPTICAL MICROSCOPY

FILE	ID	TEST SPECIMENS	OPERATOR
E-VT1			
E1000(6)		**Visual inspection of fatigue cracks in Inconel 718 and Haynes 188 flat plates, by crack length**	
E1001AL		Unaided visual inspection with 7X magnification for verification	Anonymous data using panels from the referenced work.
E1002AL		Visual inspection with 30X magnification.	Anonymous data using panels from the referenced work.
E-VT2			
E2000(4	**VT-02(4)**	**Visual inspection of J85 / sixth stage compressor disks, by crack length**	
E2006		Bolt Holes	Organization VI

APPENDIX F: X-RADIOGRAPHIC INSPECTION

FILE	ID	TEST SPECIMENS	OPERATOR
F-XT1			
F1060(1)L	**XT-01(1)A L**	**X-radiography on aluminum flat plates, 0.060" thick, by crack length**	
F10601AL	XTAAA01L-A	As Machined	Operator A
F10601BL	XTAAA01L-B	As Machined	Operator B
F10601CL	XTAAA01L-C	As Machined	Operator C
F10602AL	XTAAA02L-A	After Etch	Operator A
F10602BL	XTAAA02L-B	After Etch	Operator B
F10602CL	XTAAA02L-C	After Etch	Operator C
F10603AL	XTAAA03L-A	After Proof	Operator A
F10603BL	XTAAA03L-B	After Proof	Operator B
F10603CL	XTAAA03L-C	After Proof	Operator C
F1060(1)D	**XT-01(1)A D**	**X-radiography on aluminum flat plates, 0.060" thick, by crack depth**	
F10601AD	XTAAA01D-A	As Machined	Operator A
F10601BD	XTAAA01D-B	As Machined	Operator B
F10601CD	XTAAA01D-C	As Machined	Operator C
F10602AD	XTAAA02D-A	After Etch	Operator A
F10602BD	XTAAA02D-B	After Etch	Operator B
F10602CD	XTAAA02D-C	After Etch	Operator C
F10603AD	XTAAA03D-A	After Proof	Operator A
F10603BD	XTAAA03D-B	After Proof	Operator B
F10603CD	XTAAA03D-C	After Proof	Operator C
F1000(1)A	**XT-01(1)C a/T**	**X-radiography on aluminum flat plates, combined 0.060" and 0.220 " thicknesses, by crack depth to thickness ratio**	
F10001AA	XTAAA01a/T-A	As Machined	Operator A
F10001BA	XTAAA01a/T-B	As Machined	Operator B

APPENDIX F: X-RADIOGRAPHIC INSPECTION

FILE	ID	TEST SPECIMENS	OPERATOR
F10001CA	XTAAA01a/T-C	As Machined	Operator C
F10002AA	XTAAA02a/T-A	After Etch	Operator A
F10002BA	XTAAA02a/T-B	After Etch	Operator B
F10002CA	XTAAA02a/T-C	After Etch	Operator C
F10003AA	XTAAA03a/T-A	After Proof	Operator A
F10003BA	XTAAA03a/T-B	After Proof	Operator B
F10003CA	XTAAA03a/T-C	After Proof	Operator C
F1220(1)L	**XT-01(1)B L**	**X-radiography on aluminum flat plates, 0.220" thick, by crack length**	
F12201AL	XTAAA01L-A	As Machined	Operator A
F12201BL	XTAAA01L-B	As Machined	Operator B
F12201CL	XTAAA01L-C	As Machined	Operator C
F12202AL	XTAAA02L-A	After Etch	Operator A
F12202BL	XTAAA02L-B	After Etch	Operator B
F12202CL	XTAAA02L-C	After Etch	Operator C
F12203AL	XTAAA03L-A	After Proof	Operator A
F12203BL	XTAAA03L-B	After Proof	Operator B
F12203CL	XTAAA03L-C	After Proof	Operator C
F1220(1)D	**XT-01(1)B D**	**X-radiography on aluminum flat plates, 0.220" thick, by crack depth**	
F12201AD	XTAAA01D-A	As Machined	Operator A
F12201BD	XTAAA01D-B	As Machined	Operator B
F12201CD	XTAAA01D-C	As Machined	Operator C
F12202AD	XTAAA02D-A	After Etch	Operator A
F12202BD	XTAAA02D-B	After Etch	Operator B
F12202CD	XTAAA02D-C	After Etch	Operator C
F12203AD	XTAAA03D-A	After Proof	Operator A
F12203BD	XTAAA03D-B	After Proof	Operator B
F12203CD	XTAAA03D-C	After Proof	Operator C

FILE	ID	TEST SPECIMENS	OPERATOR
F-XT2			
F2000(1)L	**XT-02(1)A L**	**X-radiography on aluminum flat plates, 0.085" and 0.220" thicknesses, by crack length**	
F20852AL	XTAAB02L-A	After Etch, 0.085 inch thick	Operator A
F20852BL	XTAAB02L-B	After Etch, 0.085 inch thick	Operator B
F20852CL	XTAAB02L-C	After Etch, 0.085 inch thick	Operator C
F22202AL	XTAAB02L-A	After Etch, 0.220 inch thick	Operator A
F22202BL	XTAAB02L-B	After Etch, 0.220 inch thick	Operator B
F22202CL	XTAAB02L-C	After Etch, 0.220 inch thick	Operator C
F2000(1)D	**XT-01(1)A D**	**X-radiography on aluminum flat plates, 0.085" thick, and 0.220" thick by crack depth**	
F20852AD	XTAAB02D-A	After Etch, 0.085 inch thick	Operator A
F20852BD	XTAAB02D-B	After Etch, 0.085 inch thick	Operator B
F20852CD	XTAAB02D-C	After Etch, 0.085 inch thick	Operator C
F22202AD	XTAAB02D-A	After Etch, 0.220 inch thick	Operator A
F22202BD	XTAAB02D-B	After Etch, 0.220 inch thick	Operator B
F22202CD	XTAAB02D-C	After Etch, 0.220 inch thick	Operator C
F2000(1)A	**XT-01(1)C a/T**	**X-radiography on aluminum flat plates, combined 0.085" and 0.220 " thicknesses, by crack depth to thickness ratio**	
F20002AA	XTAAB02a/T-A	After Etch	Operator A
F20002BA	XTAAB02a/T-B	After Etch	Operator B
F20002CA	XTAAB02a/T-C	After Etch	Operator C

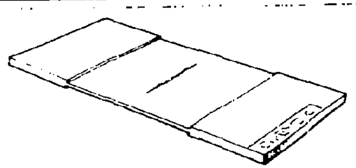
FILE	ID	TEST SPECIMENS	OPERATOR
F-XT3			
F3000(2)L	**XT-03(2)A L**	**X-radiography on titanium flat plates, 0.065" and 0.225" thickness, by crack length**	
F30651AL	XTAA01L-A	As Machined, 0.065 inch thick	Operator A
F30651BL	XTAA01L-B	As Machined, 0.065 inch thick	Operator B
F30651CL	XTAA01L-C	As Machined, 0.065 inch thick	Operator C
F30653AL	XTAA03L-A	After Proof, 0.065 inch thick	Operator A
F30653BL	XTAA03L-B	After Proof, 0.065 inch thick	Operator B
F30653CL	XTAA03L-C	After Proof, 0.065 inch thick	Operator C
F32251AL	XTAA01L-A	As Machined, 0.225 inch thick	Operator A
F32251BL	XTAA01L-B	As Machined, 0.225 inch thick	Operator B
F32251CL	XTAA01L-C	As Machined, 0.225 inch thick	Operator C
F32253AL	XTAA03L-A	After Proof, 0.225 inch thick	Operator A
F32253BL	XTAA03L-B	After Proof, 0.225 inch thick	Operator B
F32253CL	XTAA03L-C	After Proof, 0.225 inch thick	Operator C
F3000(1)D	**XT-01(1)A D**	**X-radiography on titanium flat plates, 0.065" and 0.225" thickness, by crack depth**	
F30651AD	XTAA01D-A	As Machined, 0.065 inch thick	Operator A
F30651BD	XTAA01D-B	As Machined, 0.065 inch thick	Operator B
F30651CD	XTAA01D-C	As Machined, 0.065 inc' thick	Operator C
F30653AD	XTAA03D-A	After Proof, 0.065 inch thick	Operator A
F30653BD	XTAA03D-B	After Proof, 0.065 inch thick	Operator B
F30653CD	XTAA03D-C	After Proof, 0.065 inch thick	Operator C

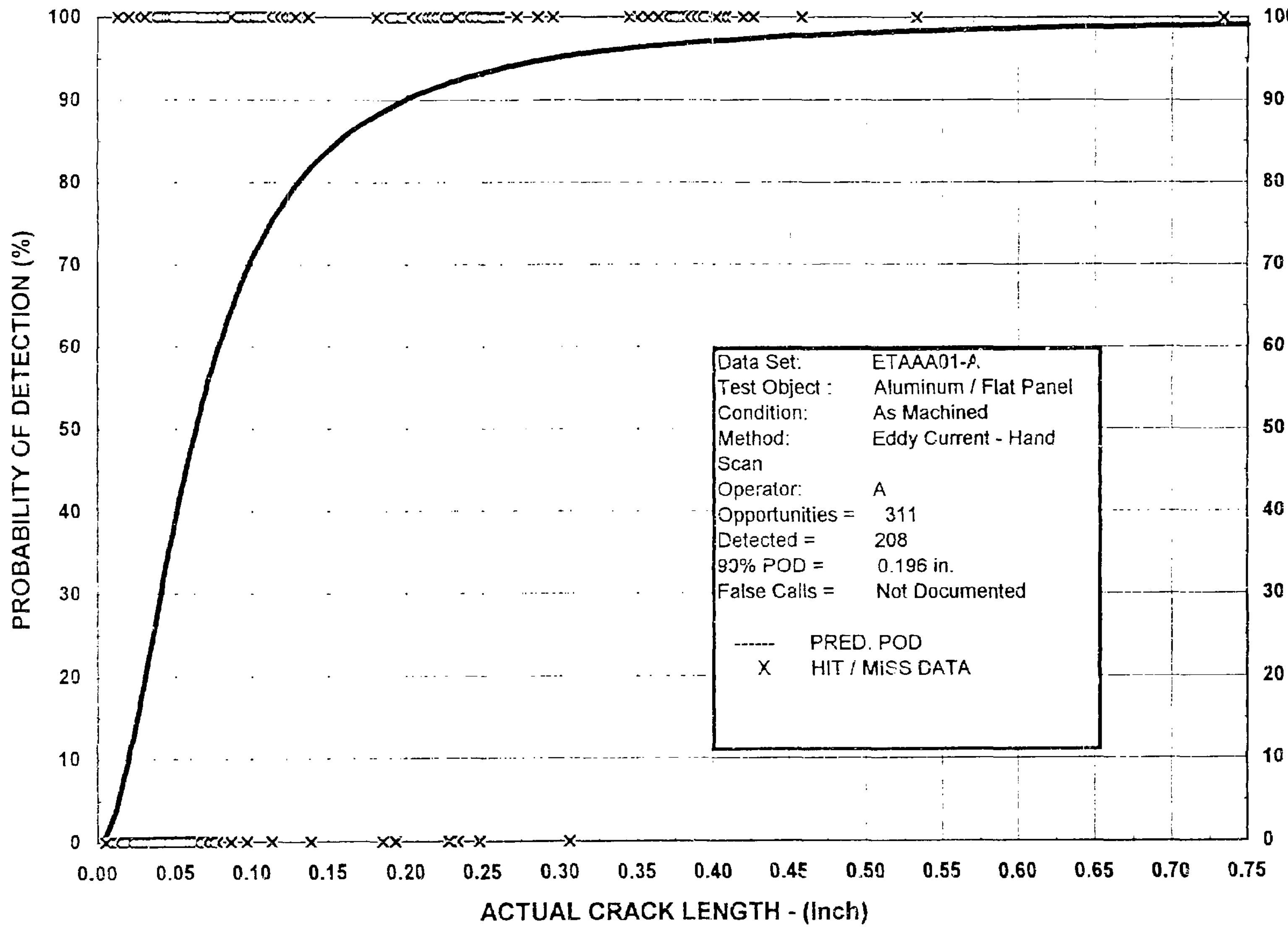
FILE	ID	TEST SPECIMENS	OPERATOR
F32251AD	XTAA01D-A	As Machined, 0.225 inch thick	Operator A
F32251BD	XTAA01D-B	As Machined, 0.225 inch thick	Operator B
F32251CD	XTAA01D-C	As Machined, 0.225 inch thick	Operator C
F32253AD	XTAA03D-A	After Proof, 0.225 inch thick	Operator A
F32253BD	XTAA03D-B	After Proof, 0.225 inch thick	Operator B
F32253CD	XTAA03D-C	After Proof, 0.225 inch thick	Operator C
F-XT4			
F4060(2)L		**X-radiography on 0.060 inch thick 4340 steel flat plates**	
F40601AL		As Machined	Operator A
F40601BL		As Machined	Operator B
F40601CL		As Machined	Operator C
F40603AL		After Etch and Proof	Operator A
F40603BL		After Etch and Proof	Operator B
F40603CL		After Etch and Proof	Operator C
F4250(2)L		**X-radiography on 0.250 inch thick 4340 steel flat plates**	
F42501AL		As Machined	Operator A
F42501BL		As Machined	Operator B
F42501CL		As Machined	Operator C
F42503AL		After Etch and Proof	Operator A
F42503BL		After Etch and Proof	Operator B
F42503CL		After Etch and Proof	Operator C
F-XT5			
F5000(3)L, D		**X-Radiographic Inspection of Lack of Penetration (LOP) Defects in Aluminum Alloy GTA Welds**	Combined - 3 Operators
F5001(3)L		As Welded and Scarfed	By Length
F5002(3)L		After Etch	
F5003(3)L		After Proof Loading	
F5001(3)D		As Welded and Scarfed	By Depth
F5002(3)D		After Etch	
F5003(3)D		After Proof Loading	

APPENDIX F: X-RADIOGRAPHIC INSPECTION

FILE	ID	TEST SPECIMENS	OPERATOR
F-XT6			
F6000(3)L, D		**X-Radiographic Inspection of Longitudinal Fatigue Cracks in Welds with Crowns**	Combined - 3 Operators
F6001(3)L		As Welded and Scarfed	By Length
F6002(3)L		After Etch	
F6003(3)L		After Proof Loading	
F6001(3)D		As Welded and Scarfed	By Depth
F6002(3)D		After Etch	
F6003(3)D		After Proof Loading	
F-XT7			
F7000(3)L, D		**X-Radiographic Inspection of Transverse Fatigue Cracks in Welds with Crowns**	Combined - 3 Operators
F7001(3)L		As Welded and Scarfed	By Length
F7002(3)L		After Etch	
F7003(3)L		After Proof Loading	
F7001(3)D		As Welded and Scarfed	By Depth
F7002(3)D		After Etch	
F7003(3)D		After Proof Loading	
F-XT8			
F8000(3)L, D		**X-Radiographic Inspection of Longitudinal Fatigue Cracks in Flush Welds**	Combined - 3 Operators
F8001(3)L		As Welded and Scarfed	By Length
F8002(3)L		After Etch	
F8003(3)L		After Proof Loading	
F8001(3)D		As Welded and Scarfed	By Depth
F8002(3)D		After Etch	
F8003(3)D		After Proof Loading	
F-XT9			
F9000(3)L, D		**X-Radiographic Inspection of Transverse Fatigue Cracks in Flush Welds**	
F9001(3)L		As Welded and Scarfed	By Length
F9002(3)L		After Etch	
F9003(3)L		After Proof Loading	
F9001(3)D		As Welded and Scarfed	By Depth
F9002(3)D		After Etch	
F9003(3)D		After Proof Loading	

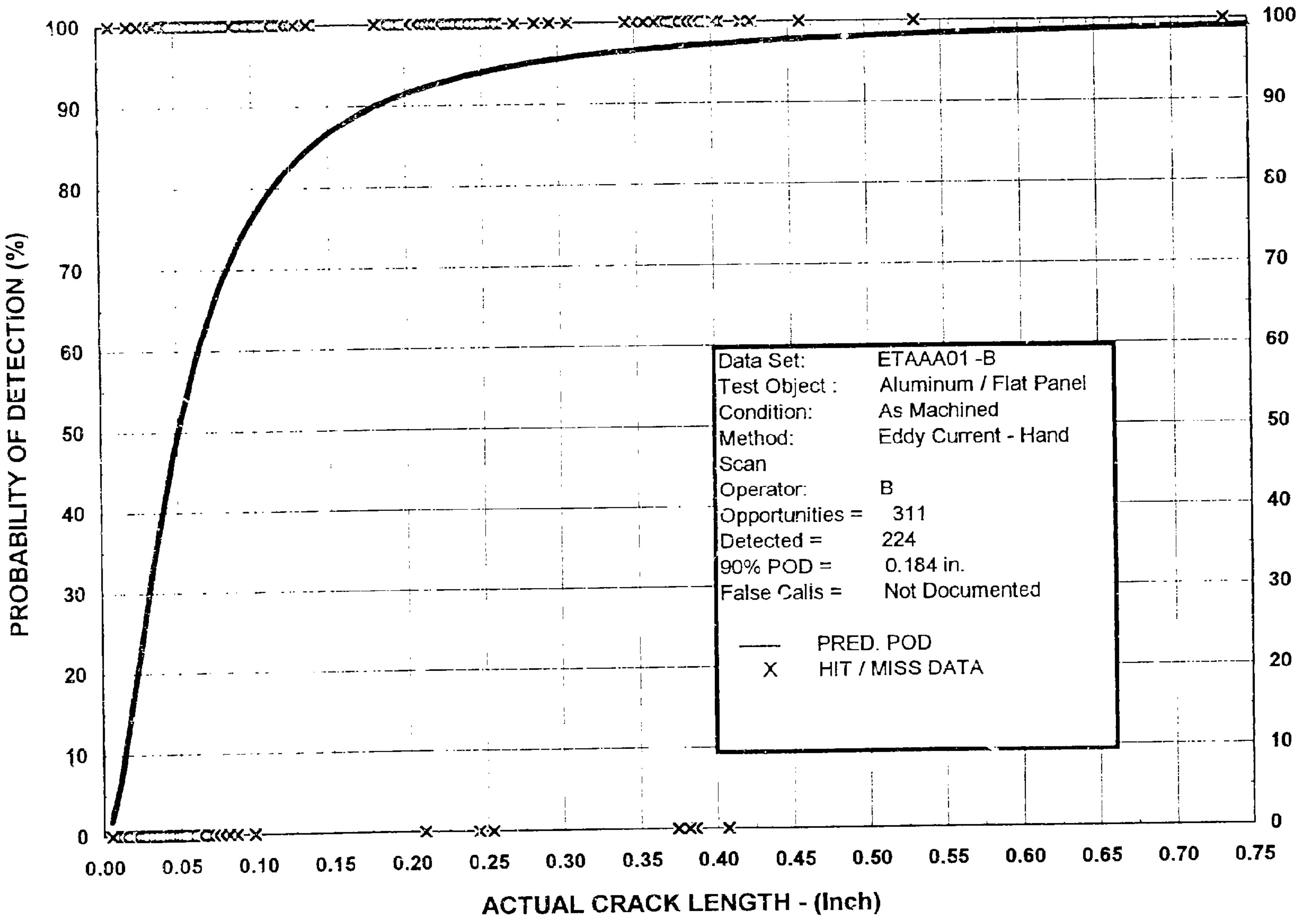
FILE	ID	TEST SPECIMENS	OPERATOR
G-ZT			
G1000(1L	**ZT-01(1)**	**Holographic Interferometry on aluminum flat plates**	
G10003AL	ZTAAA03L-A	After Proof, by Length	Operator A
G10003BL	ZTAAA03L-B	After Proof, by Length	Operator B
G10003AD	ZTAAA03D-A	After Proof, by Depth	Operator A
G10003BD	ZTAAA03D-B	After Proof, by Depth	Operator B
G10003AA	ZTAAA03a/T-A	After Proof, by Crack Depth to Thickness Ratio	Operator A
G10003BA	ZTAAA03a/T-B	After Proof, by Crack Depth to Thickness Ratio	Operator B
G-ZT2			
G2000(7)L		**"Edge of Light" inspection on J85 / seventh stage compressor disks, by crack length**	
G2001L		Bolt Holes	Organization A

ET - 01 (1) CRACK LENGTH	DATA SET DESCRIPTION		
METHOD:	Eddy Current		
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides		
NDE PROCEDURE:	Eddy Current - Contact Probe 100 kHz. Meter Readout		
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension		
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)		
ARTIFACT VERIFICATION:	Destructive analysis and measurement		
MATERIAL:	2219 Aluminum T-87		
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal		
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,B1"After Proof"		
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices		
APPLICATION:	Hand Scanning - Manual Readout		
DATA SET IDENTIFIER:	ETAAA01-A,B,C; ETAAA02-A,B,C; ETAAA03-A,B,C		
TYPE OF DATA:	Hit / Miss with estimated crack lengths		
TEST OPPORTUNITIES:	311 Cracks		
DETECTED:	ETAAA01-A= 208, B= 224, C= 205; 02-A= 228, B= 273, C= 243; 03-A= 264, B= 268, C= 266		
FALSE CALLS:	Not reported		
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.		
DATE:	November 1971 - June 1973		
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center		
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado		
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).		
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels		
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.		
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.		
	90% POD Length - "AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= 0.196 in.	A= 0.198 in.	A= 0.052 in.
	B= 0.184 in.	B= 0.071 in.	B= 0.037 in.
	C= 0.295 in.	C= 0.270 in.	C= 0.0871 in.



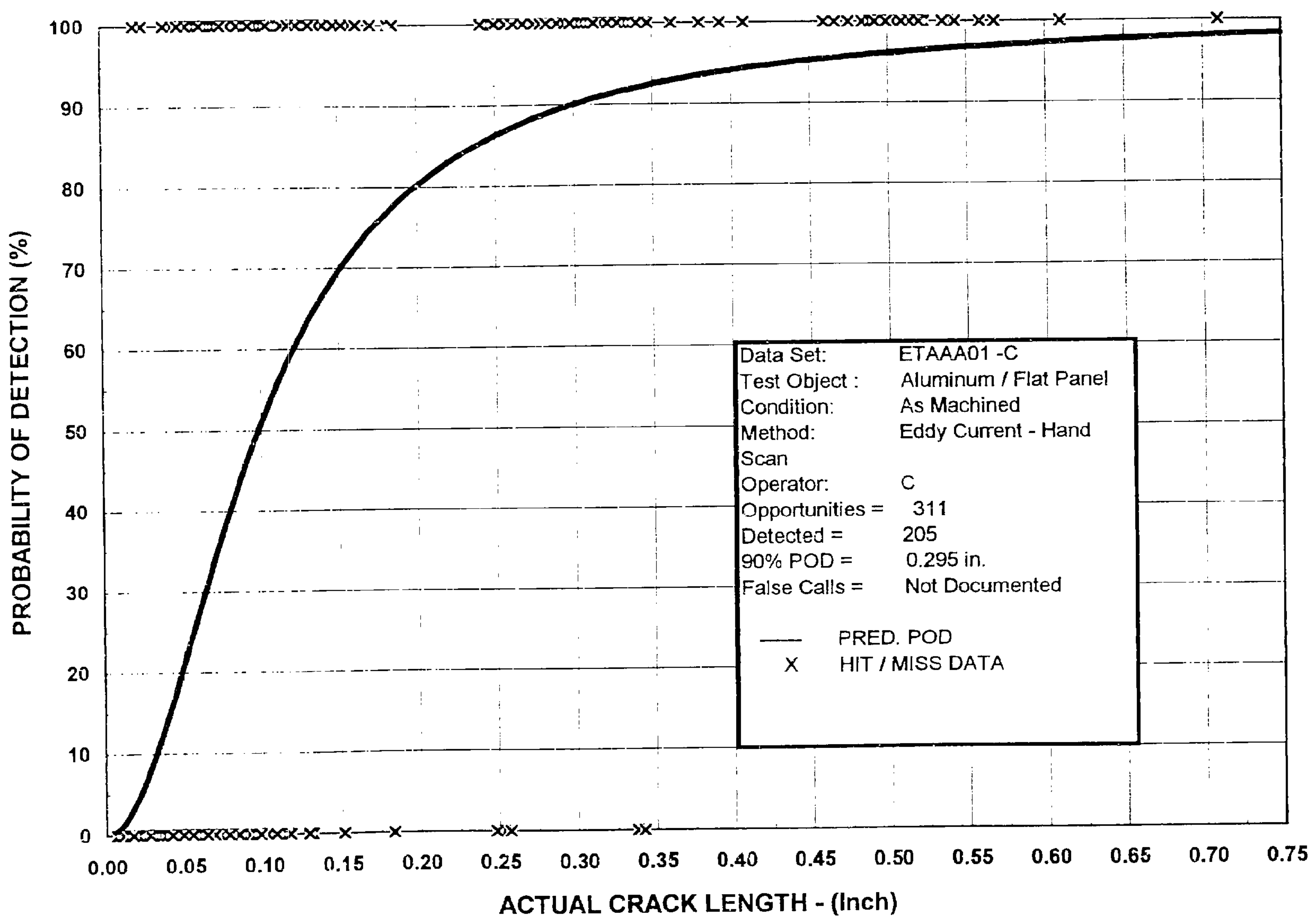
ET - 01 (1) CRACK LENGTH
06/95- A1000.1AL

ETAAA01-A
Aluminum - Flat Plate



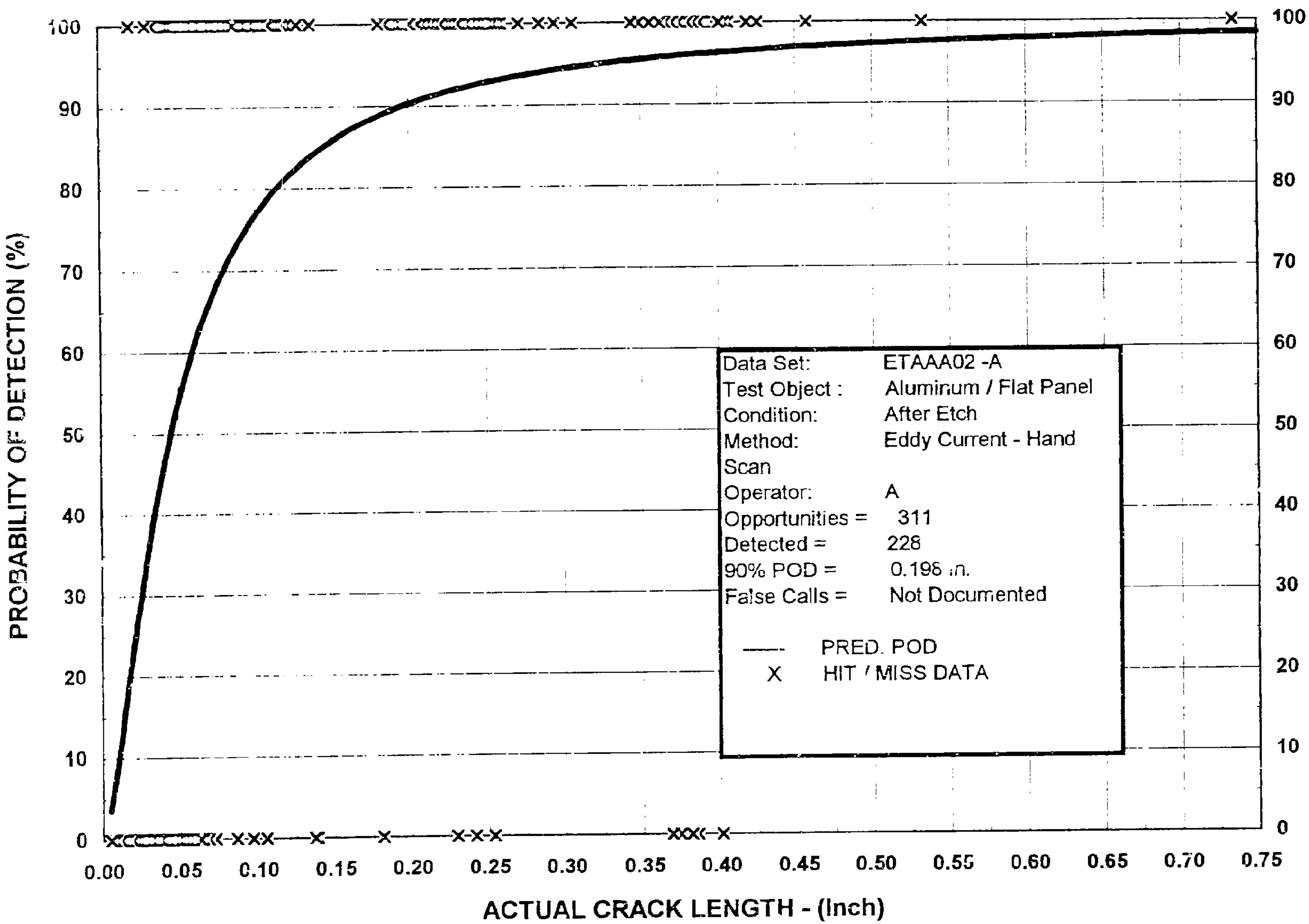
ET - 01 (1) CRACK LENGTH
06/95

ETAAA01-B
Aluminum - Flat Plate



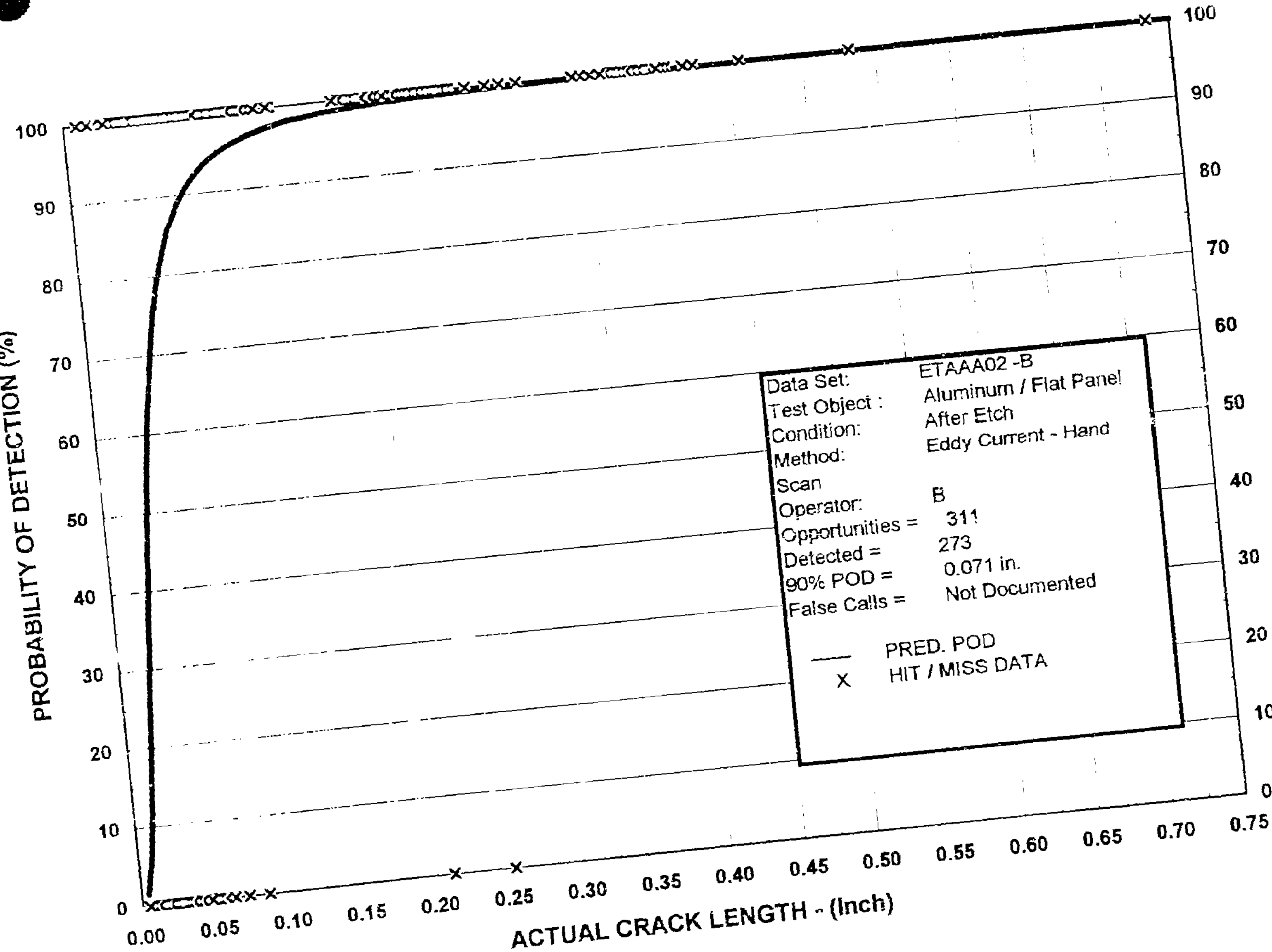
ET - 01 (1) CRACK LENGTH
06/95

ETAAA01-C
Aluminum - Flat Plate



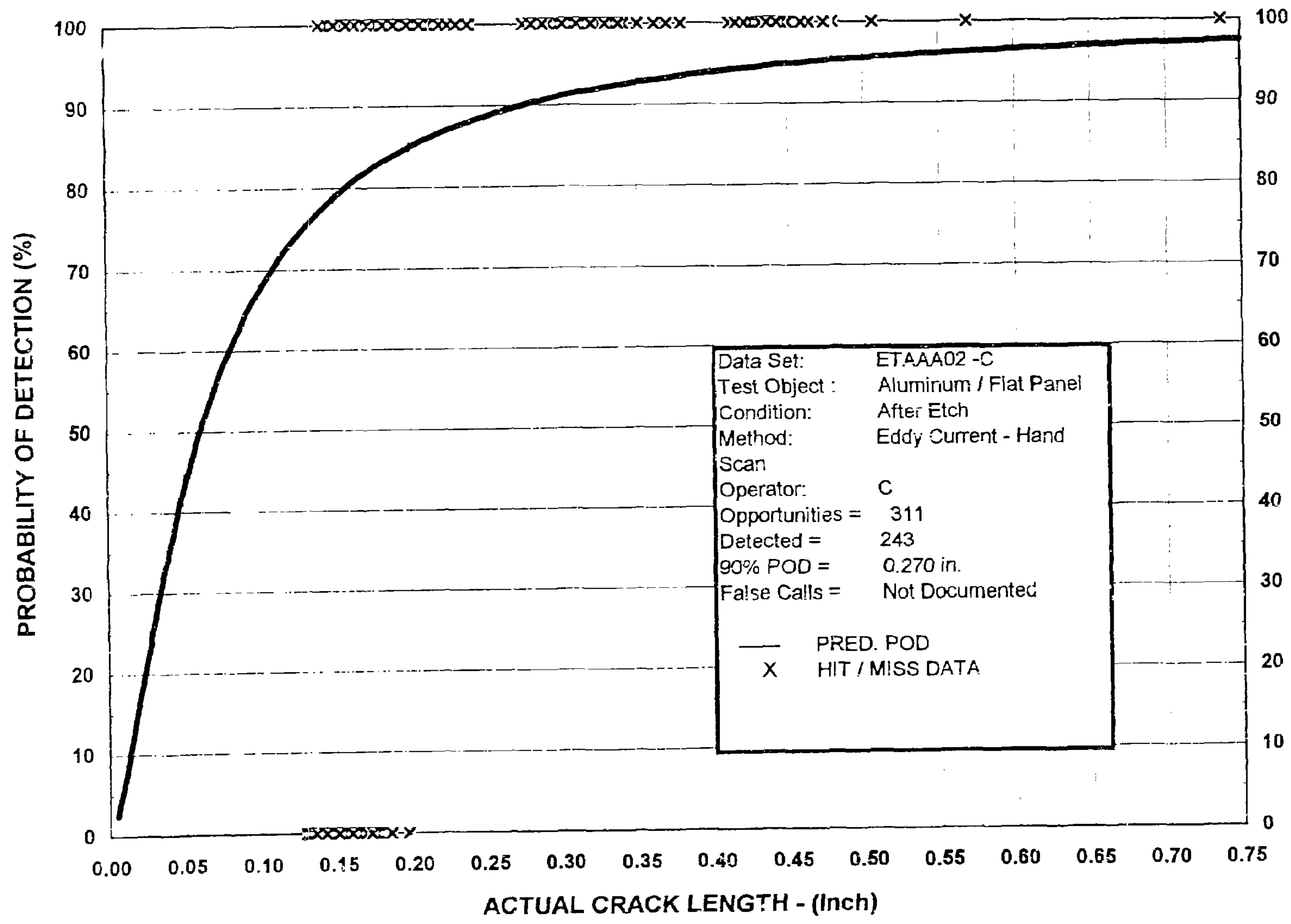
ET - 01 (1) CRACK LENGTH
06/95

ETAAA02-A
Aluminum - Flat Plate



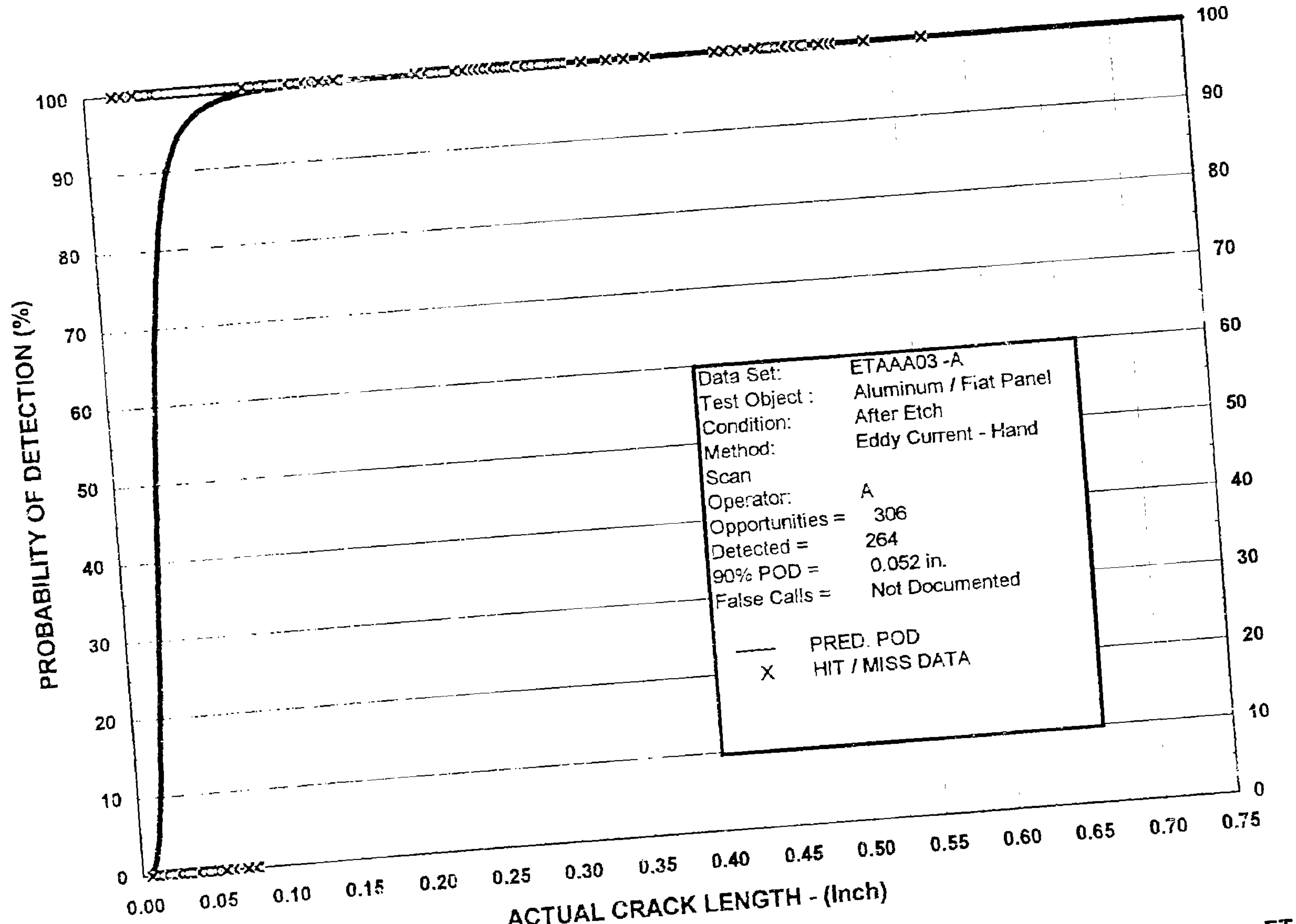
ETAAA02-B
Aluminum - Flat Plate

ET - 01 (1) CRACK LENGTH
06/95



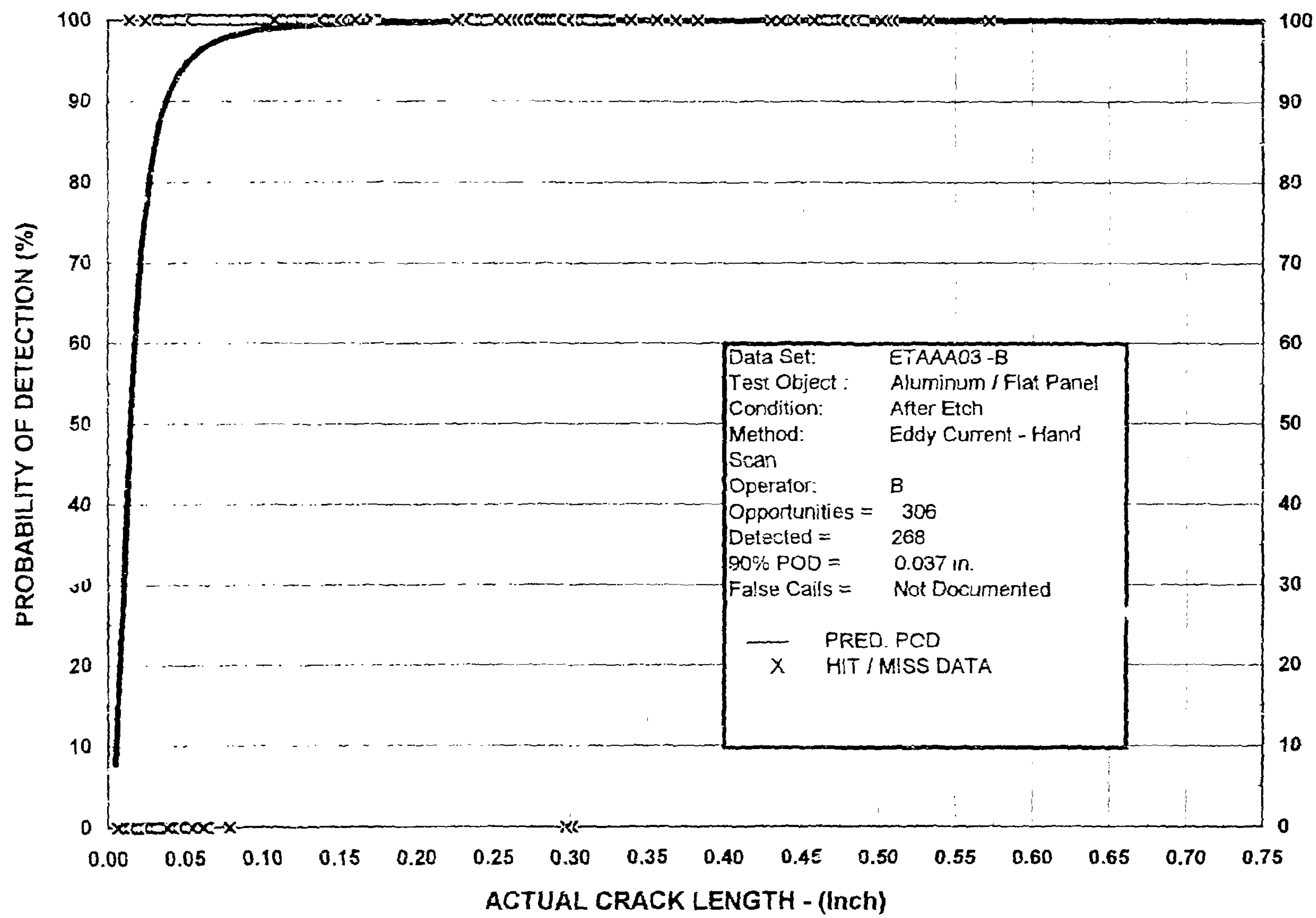
ET - 01 (1) CRACK LENGTH
06/95

ETAAA02-C
Aluminum - Flat Plate



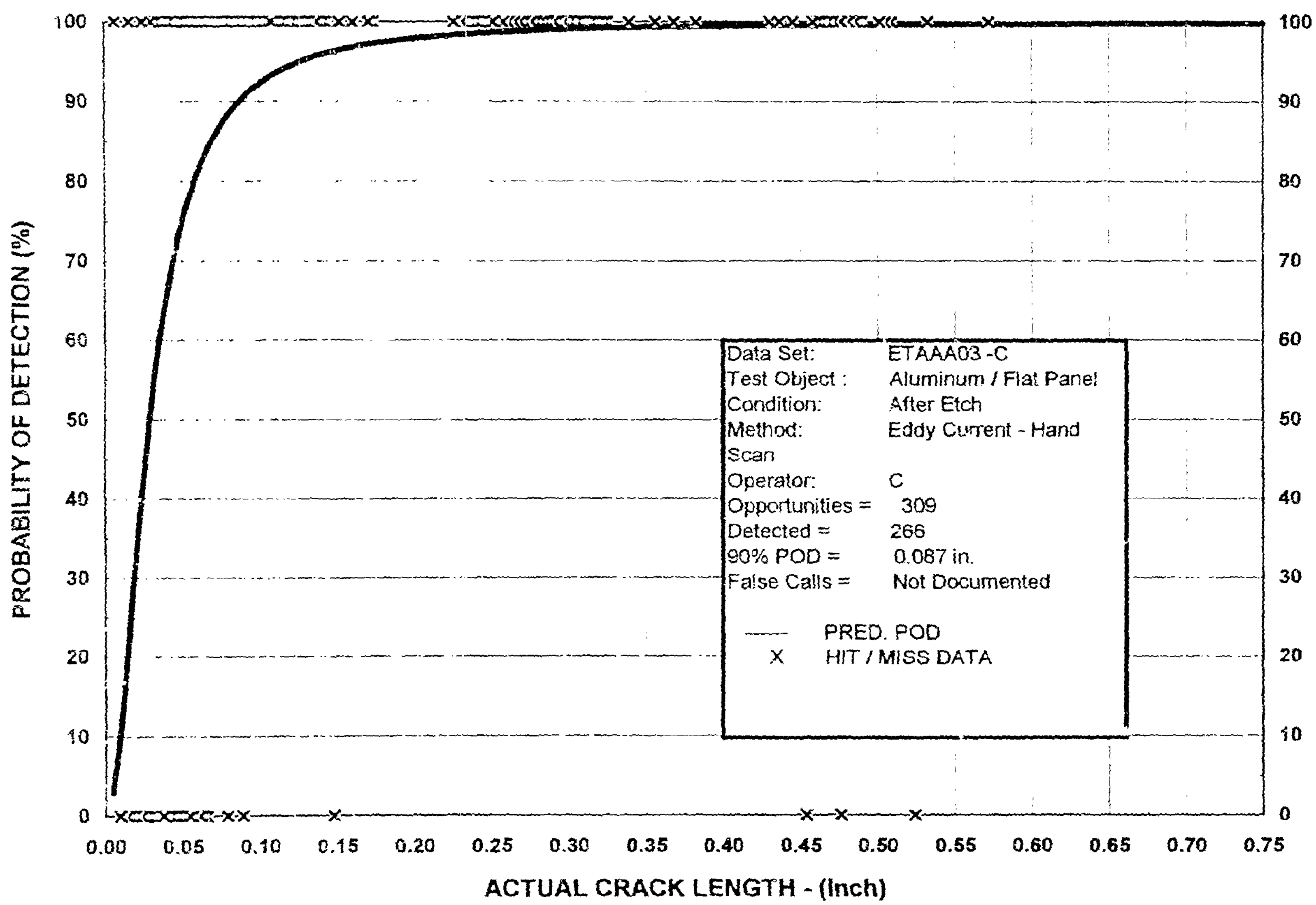
ETAAA03-A
Aluminum - Flat Plate

ET - 01 (1) CRACK LENGTH
06/95



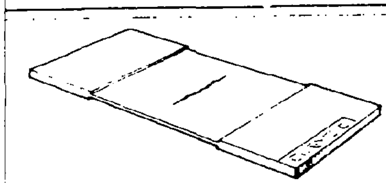
ET - 01 (1) CRACK LENGTH
06/95

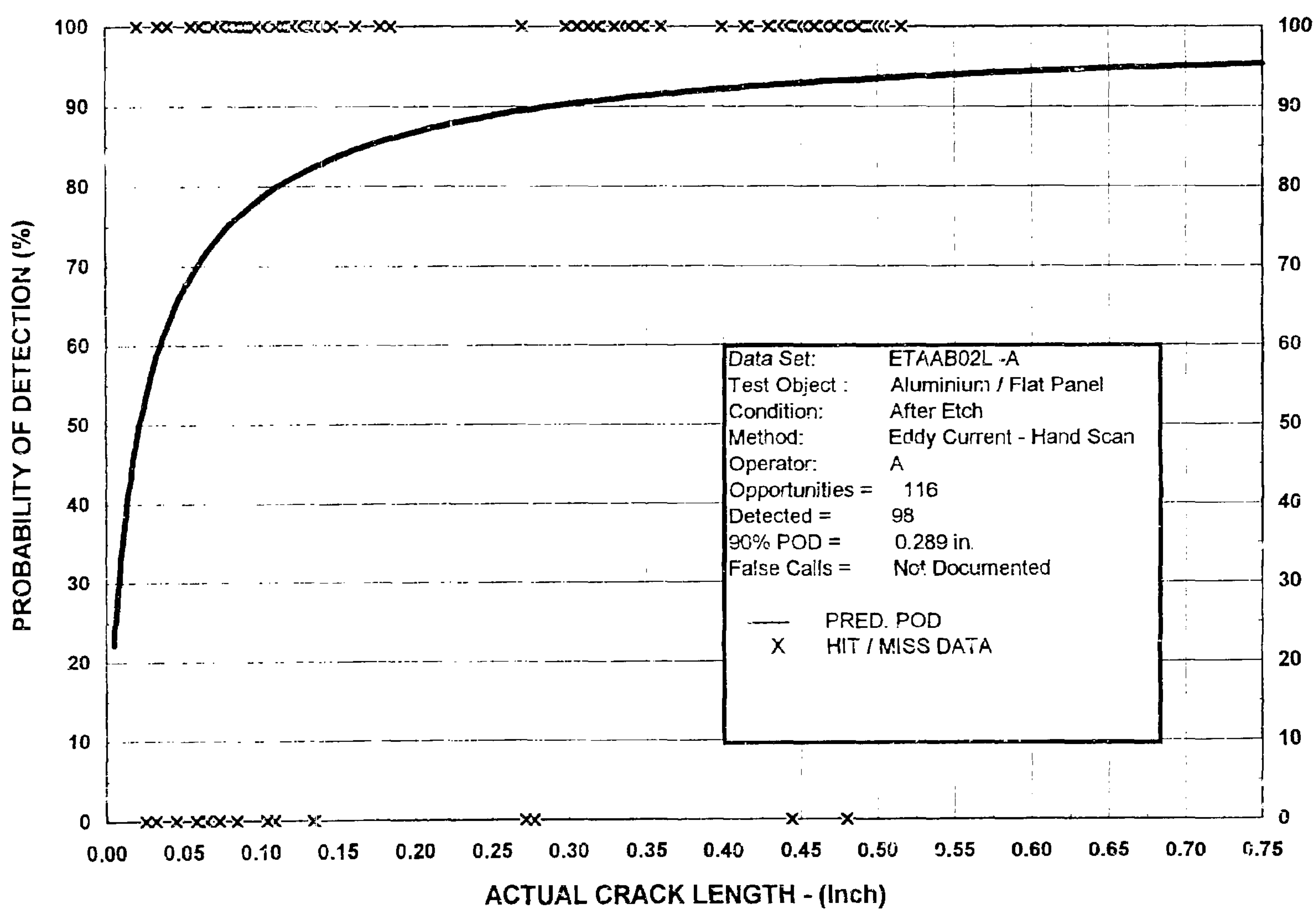
ETAAA03-B
Aluminum - Flat Plate



ET - 01 (1) CRACK LENGTH
06/95

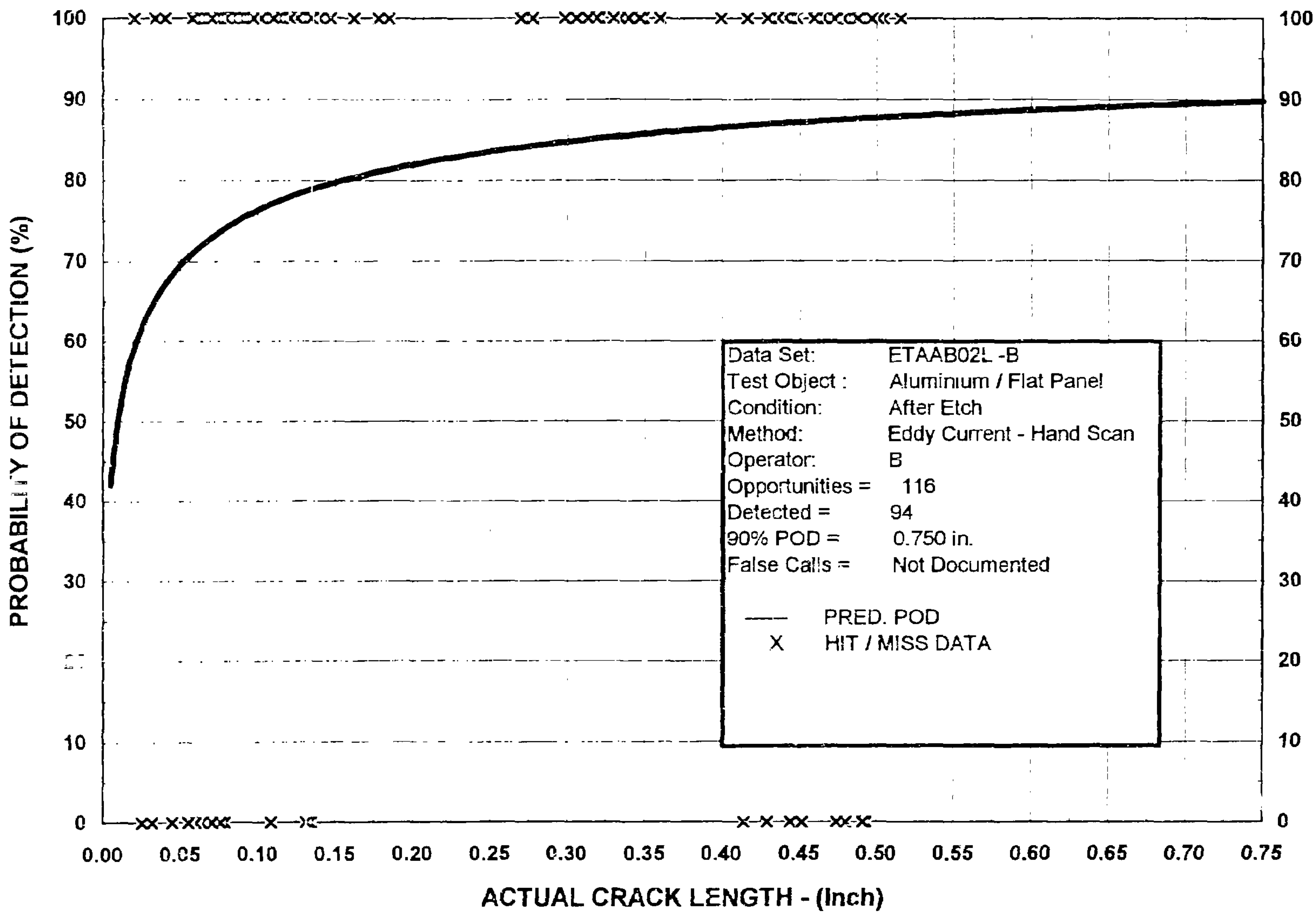
ETAAA03-C
Aluminum - Flat Plate

ET - 02 (1)	**DATA SET DISCRIPTION**
METHOD:	Eddy Current
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches. cracks on both sides (General Dynamics Panels)
NDE PROCEDURE:	Eddy Current - Contact probe: 100 kHz, Meter read-out
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	-02."After Etch"
SURFACE FINISH:	125 and 32 RMS - *representative of good machining practices*
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	ETAAB02L-A.B.C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	116 Cracks
DETECTED:	ETAAB02L -A= 98, B= 94. C= 108
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **<u>The Detection of Fatigue Cracks by Nondestructive Testing Methods</u>**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner. NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed *in support of the National Aeronautics Administration* (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**
	90% POD "AFTER ETCH"
	A= 0.289 in..
	B= 0.750 in.
	C= 0.095 in.



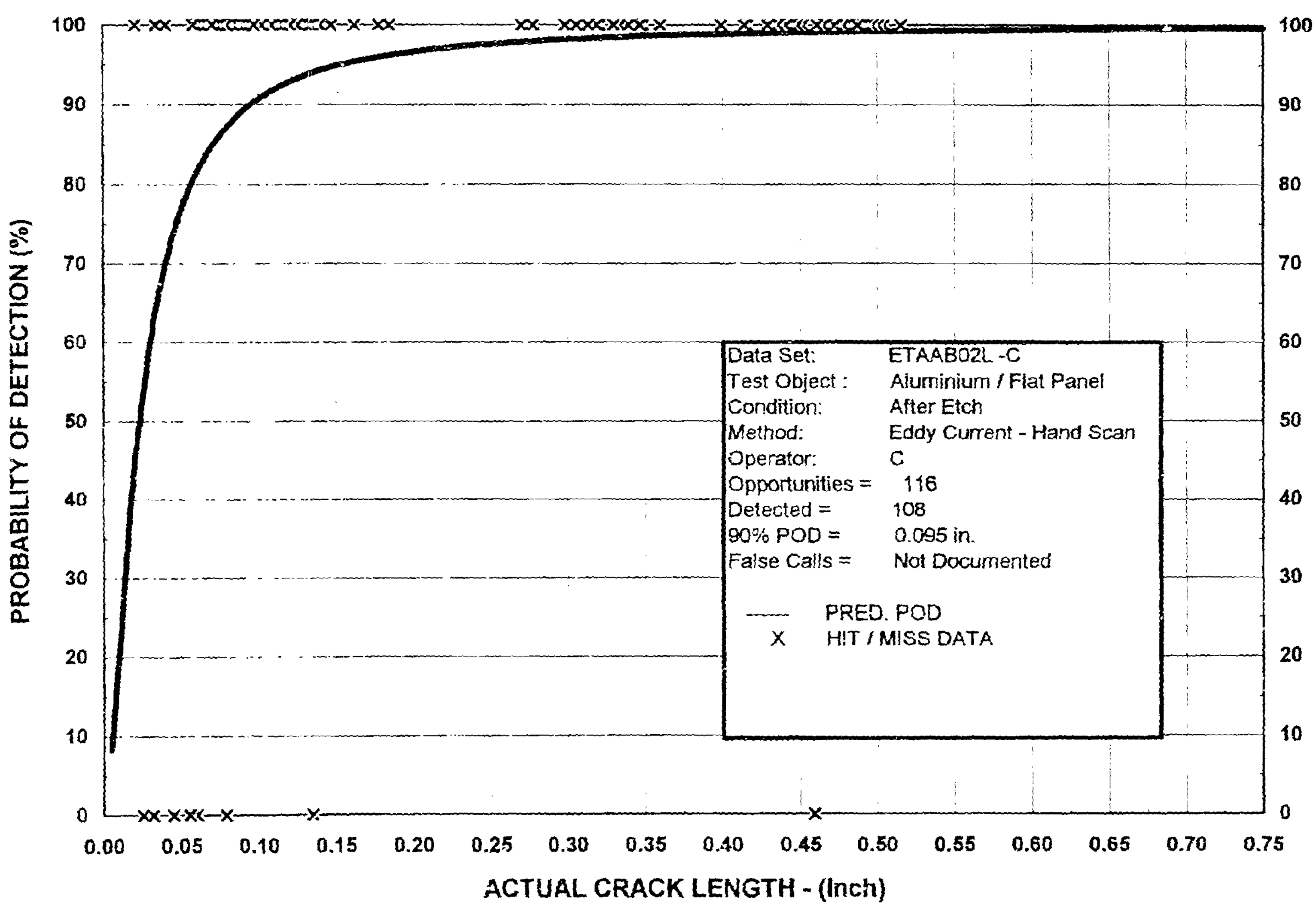
ET - 02 (1) EDDY CURRENT - HAND SCAN
GENERAL DYNAMICS ALUMINUM PANELS
6/95

ETAAB02L-A
AFTER ETCH - OPERATOR A



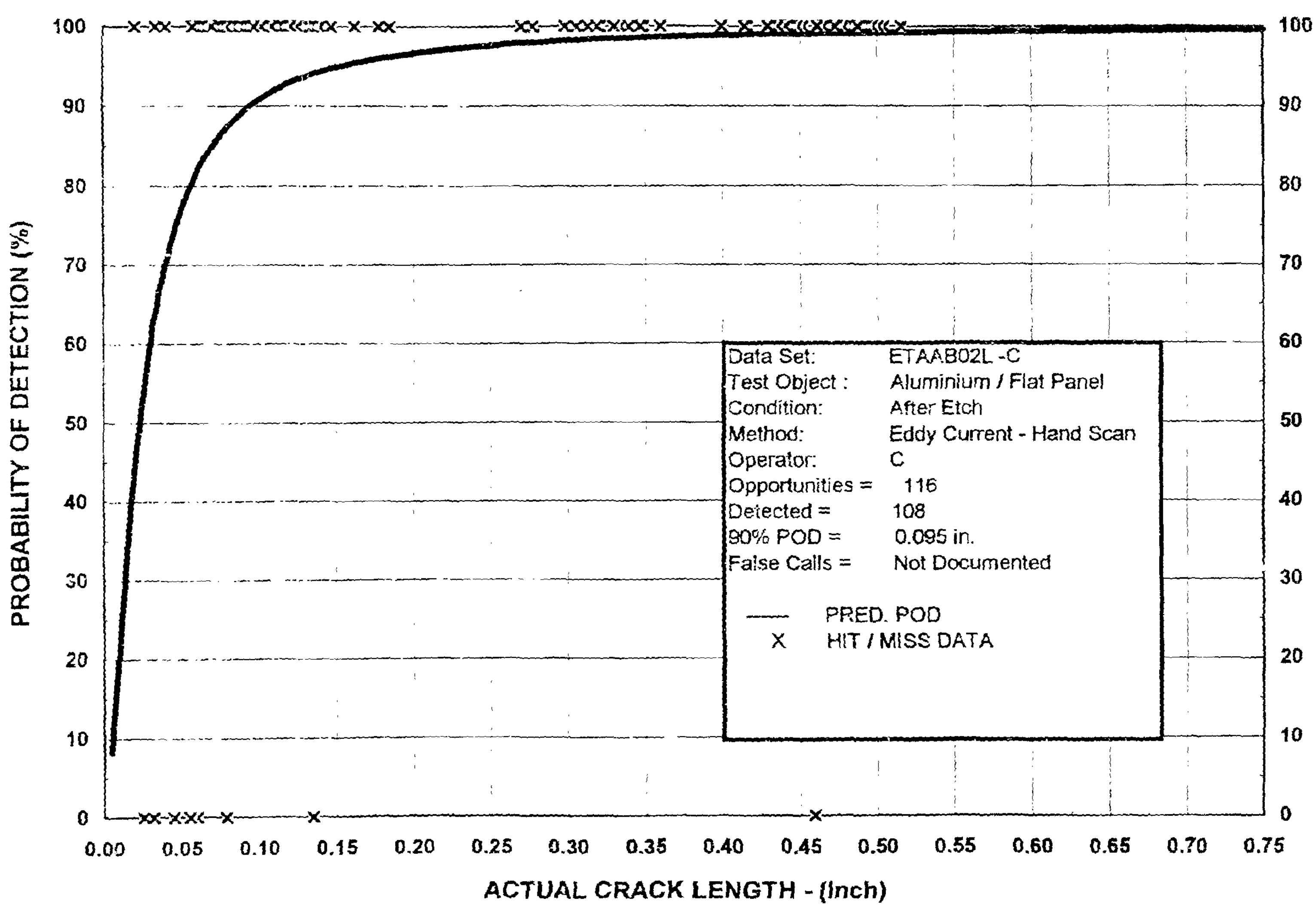
ET - 02 (1) EDDY CURRENT - HAND SCAN
GENERAL DYNAMICS ALUMINUM PANELS
6/95

ETAAB02L-B
AFTER ETCH - OPERATOR B



ET - 02 (1) EDDY CURRENT - HAND SCAN
GENERAL DYNAMICS ALUMINUM PANELS
6/95

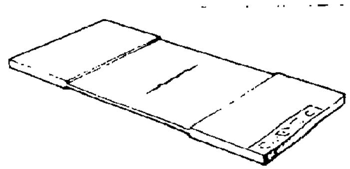
ETAAB02L-C
AFTER ETCH - OPERATOR C



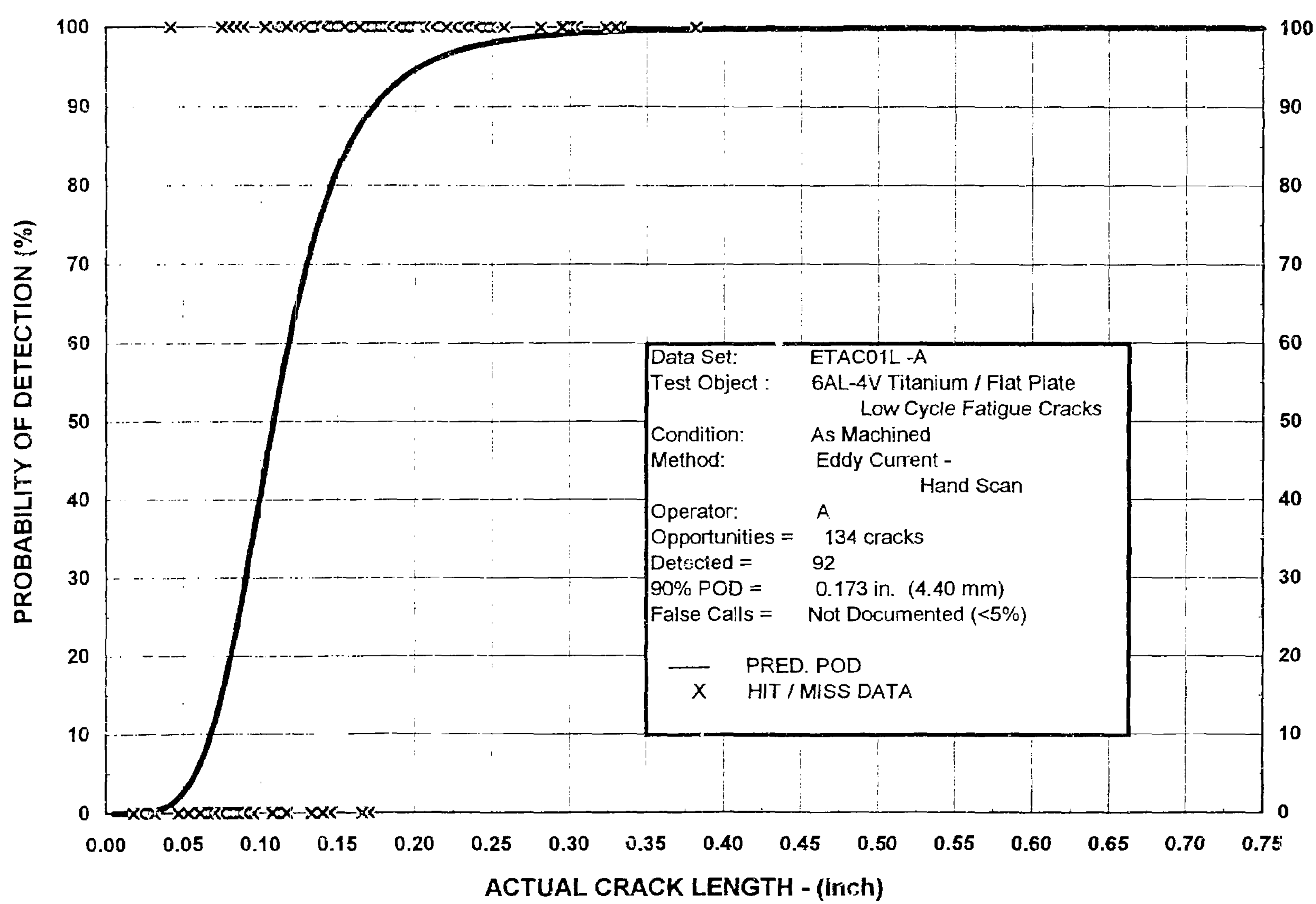
ET - 02 (1) EDDY CURRENT - HAND SCAN
GENERAL DYNAMICS ALUMINUM PANELS
6/95

ETAAB02L-C
AFTER ETCH - OPERATOR C

ET 03 (2)	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Eddy Current - Contact probe; 3 MHz, Meter read-out
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Titanium plate - 6Al4V
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02."After Etch", -03,B1"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	ETAA01L - A,B,C; ETAA03L - A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	135 Cracks (161 original - Some cracks lost in machining)
DETECTED:	ETAA01L - A = 92, B= 85, C= 89; 03L - A= 78,B= 118,C= 118
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.

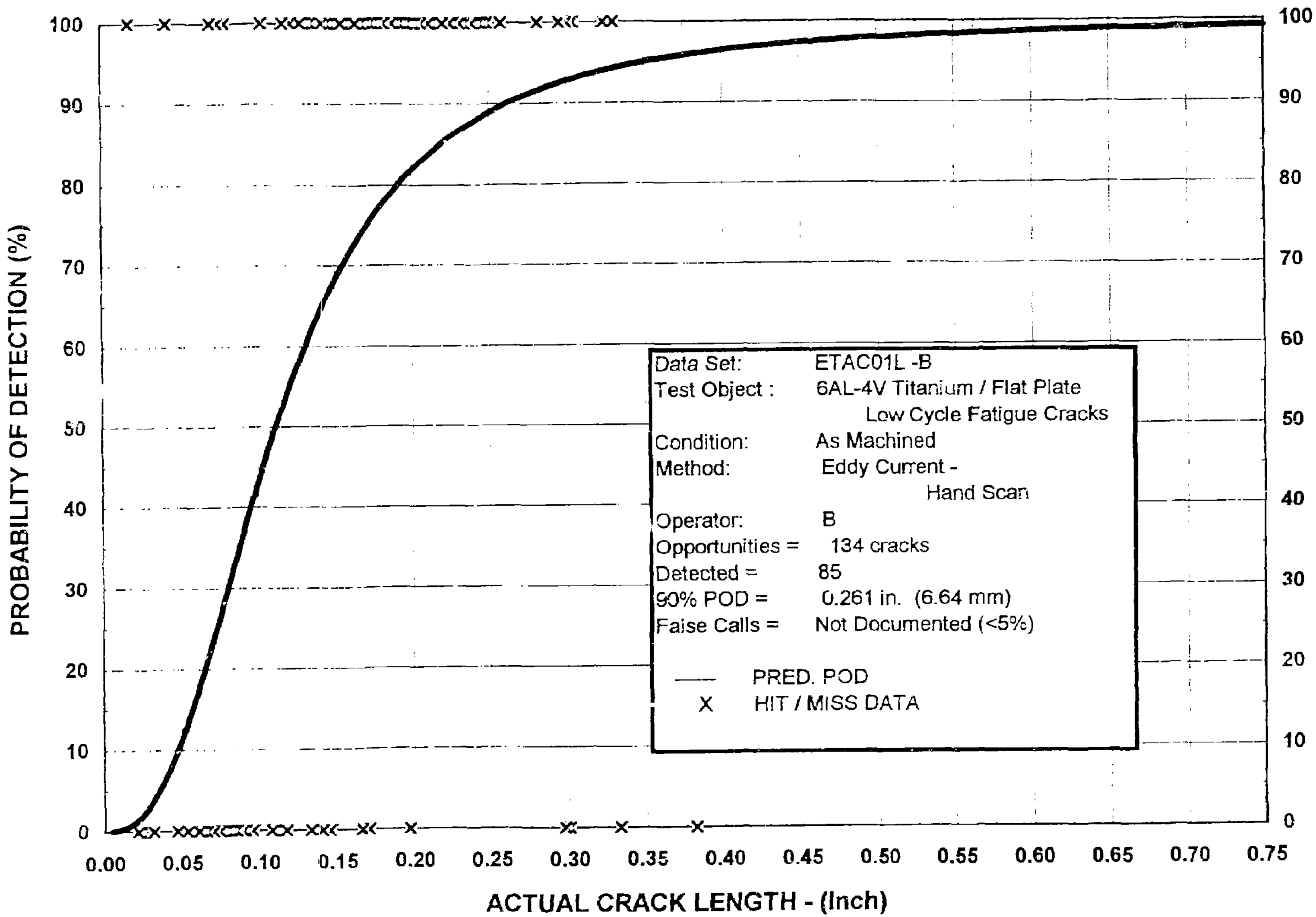


90% POD	"AS MACHINED"	"AFTER PROOF"
	A= 0.173 in. (4.40 mm)	A= 0.270 in (6.87 mm)
	B= 0.261 in. (6.64 mm)	B= 0.489 in. (12.4 mm)
	C= 0.177 in. (4.50 mm)	C= 0.581 in. (14.76 mm)



ETAC01L-A
AS MACHINED - OPERATOR A

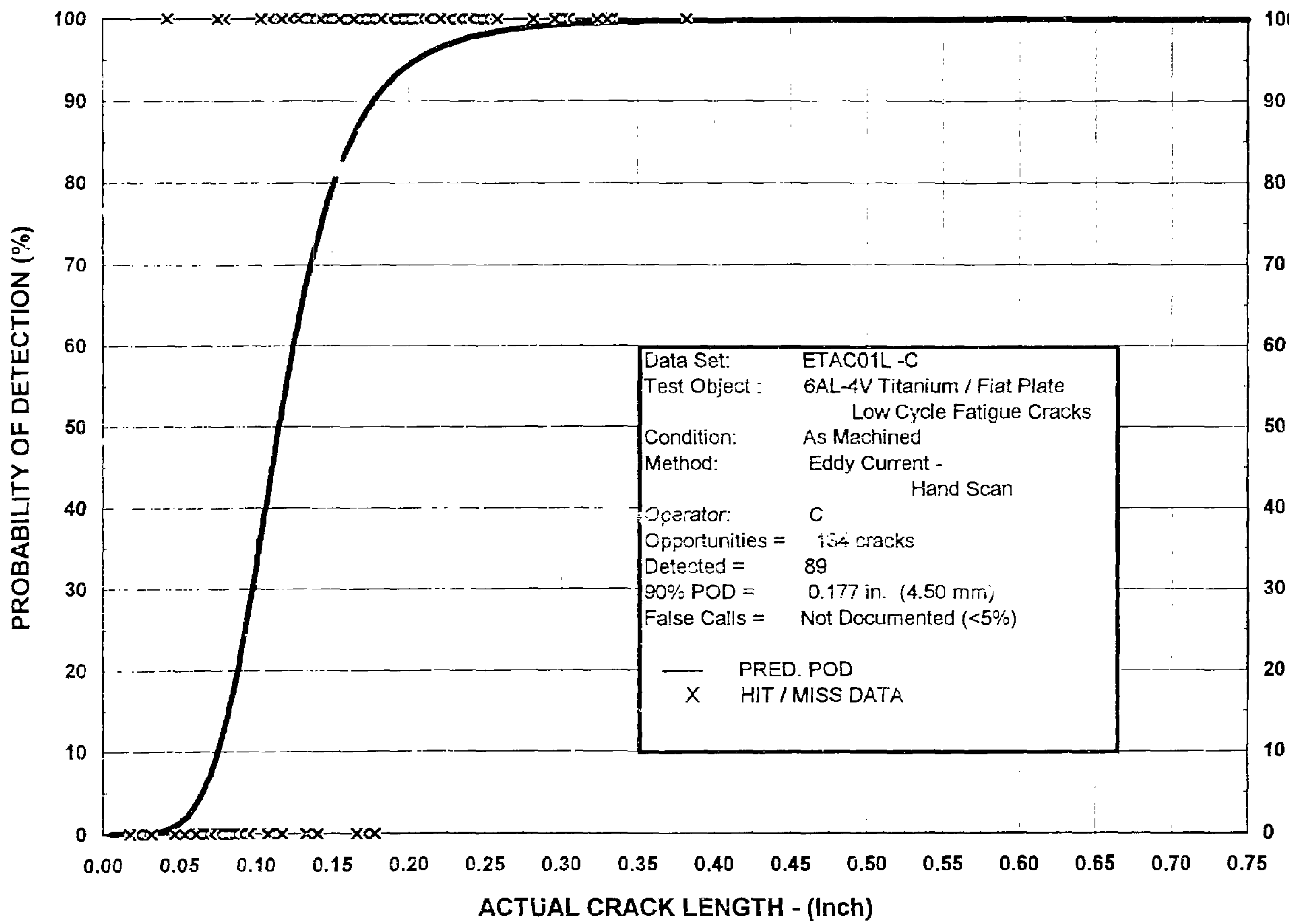
ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS
6/95



ETAC01L-B
AS MACHINED - OPERATOR B

ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS

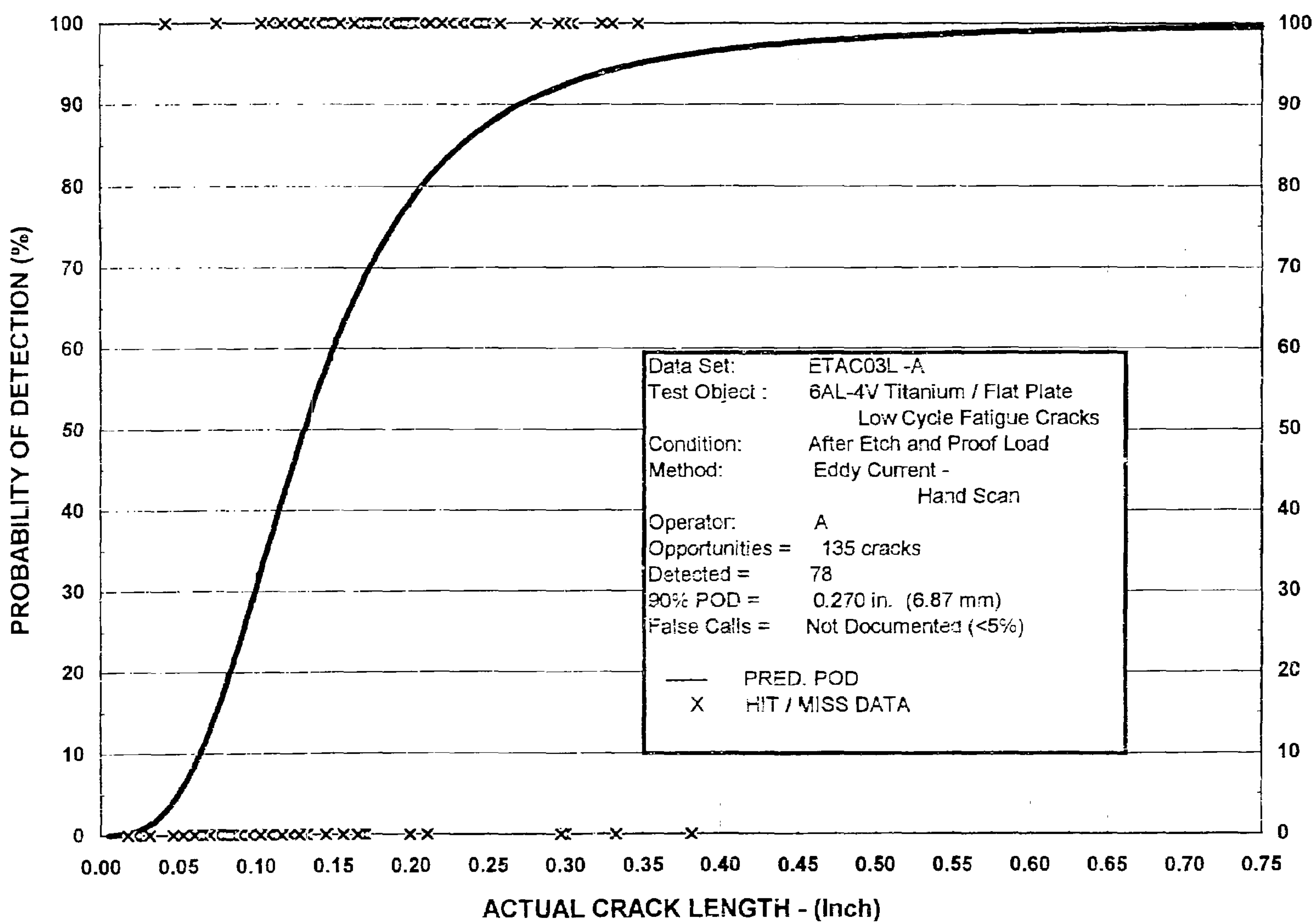
6/95



ETAC01L-C
AS MACHINED - OPERATOR C

ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS

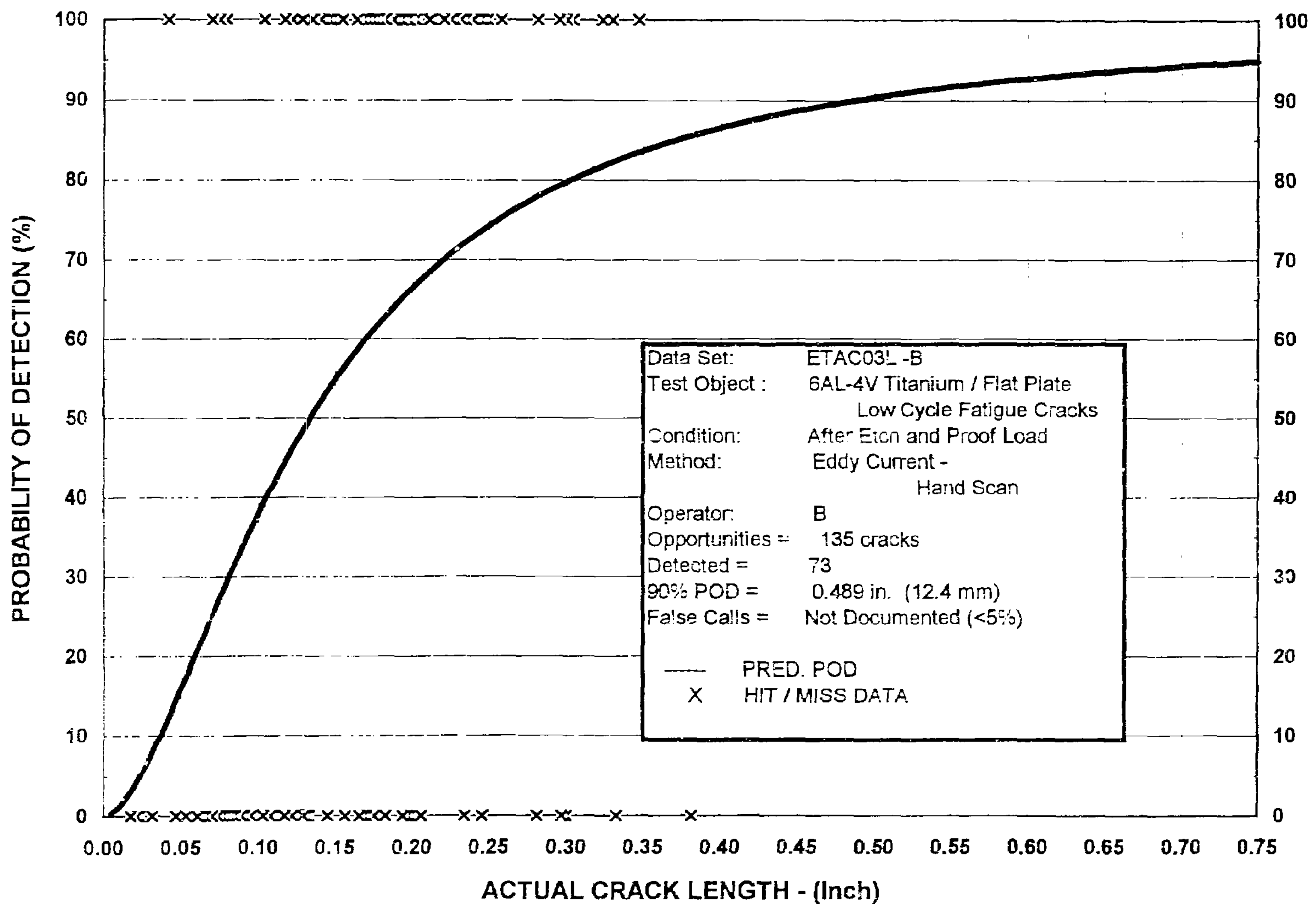
6/95



ETAC03L-A
AFTER PROOF - OPERATOR A

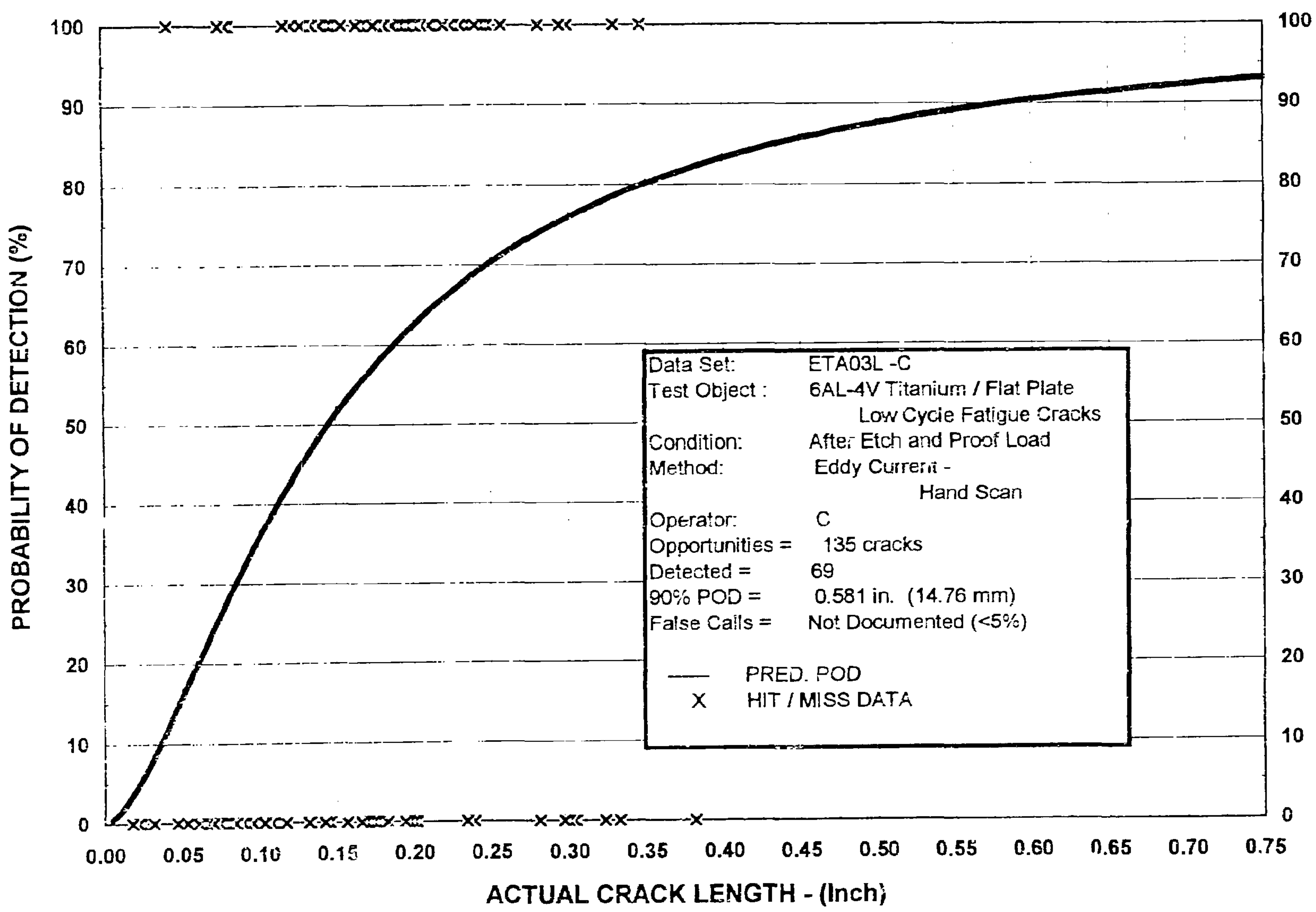
ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS

6/95



ETAC03L-B
AFTER PROOF - OPERATOR B

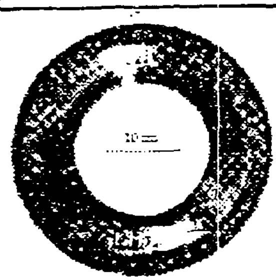
ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS
6/95

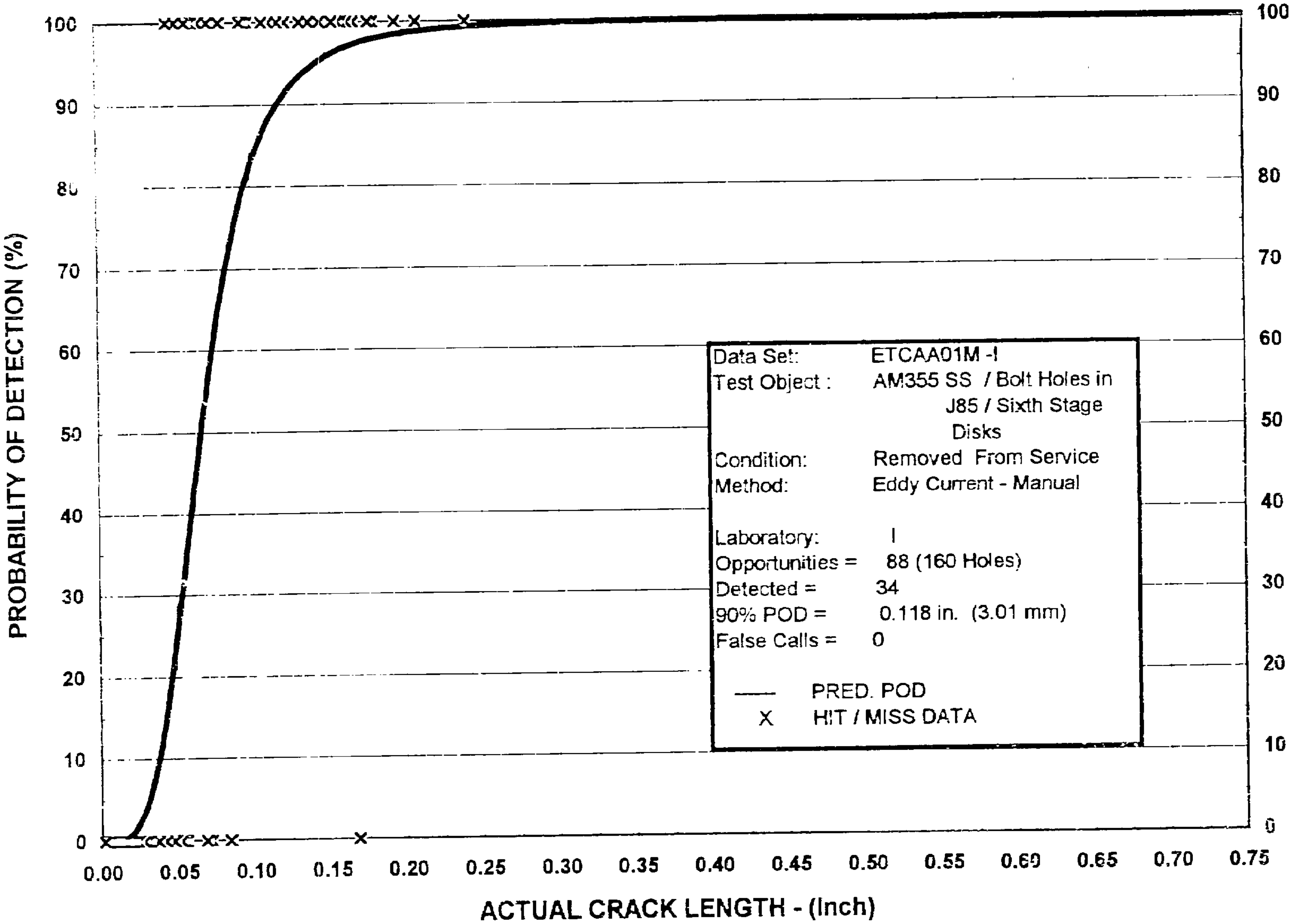


ETAC03L-C
AFTER PROOF - OPERATOR C

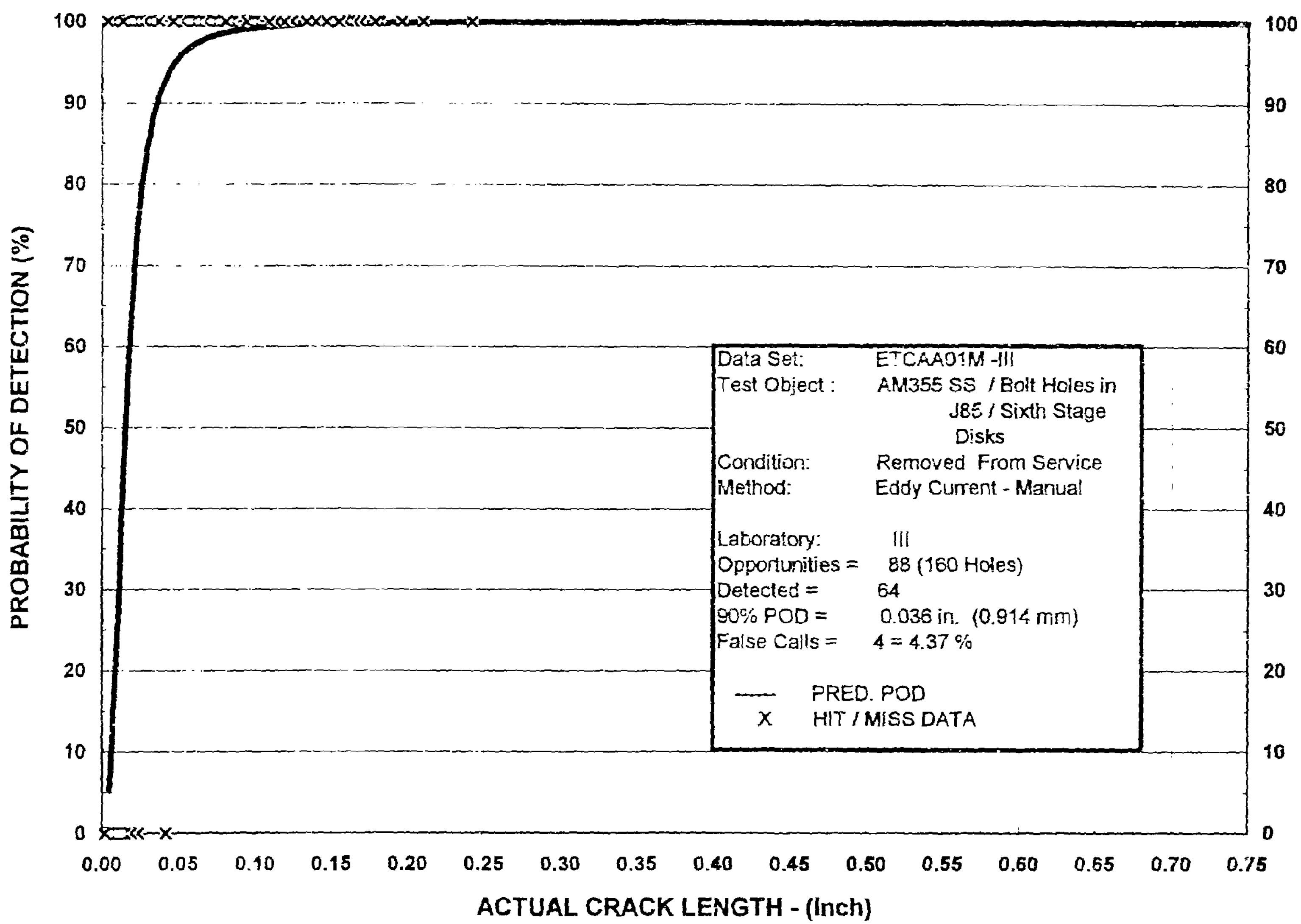
ET - 03 (2) EDDY CURRENT INSPECTION OF TITANIUM PANELS

6/95

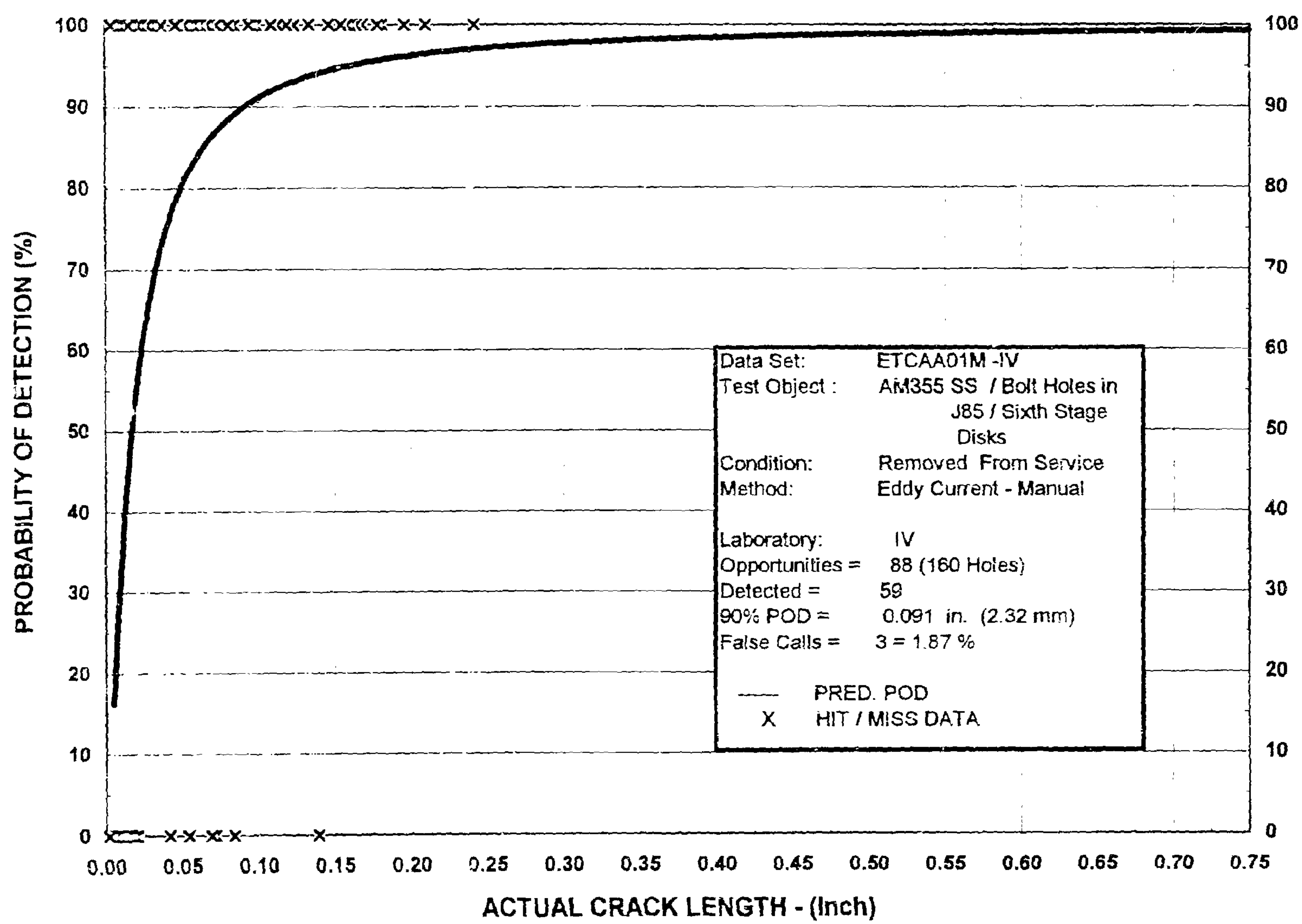
ET- 04 (4)	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Bolt holes in J85 / Sixth stage compressor disks: 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Eddy current, bolt holes, manual inspection
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	ETCAA01M -I; ETCAA01M -III; ETCAA01M -IV; ETCAA01M -V; AND ETCAA01M -VI
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	I: 160 holes/88 cracks ; III: 160 holes/88 cracks; IV: 160 holes/88 cracks; V: 160 holes/88 cracks: VI: 160 holes/88 cracks
DETECTED:	ORG I: 34; ORG III: 64; ORG IV: 59; ORG V: 70; ORG VI: 73
FALSE CALLS:	ORG I: 0; ORG III: 4 = 4.37% ; ORG IV: 3 = 1.87 %; ORG V:9 = 5.63%; ORG VI: 9 = 5.63%
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG I: 0.118 in. (3.01mm)
	ORG III: 0.036 in. (0.914mm)
	ORG IV: 0.091 in. (2.32mm)
	ORG V: 0.033 in. (0.837mm)
	ORG VI: 0.022 in. (0.556mm)

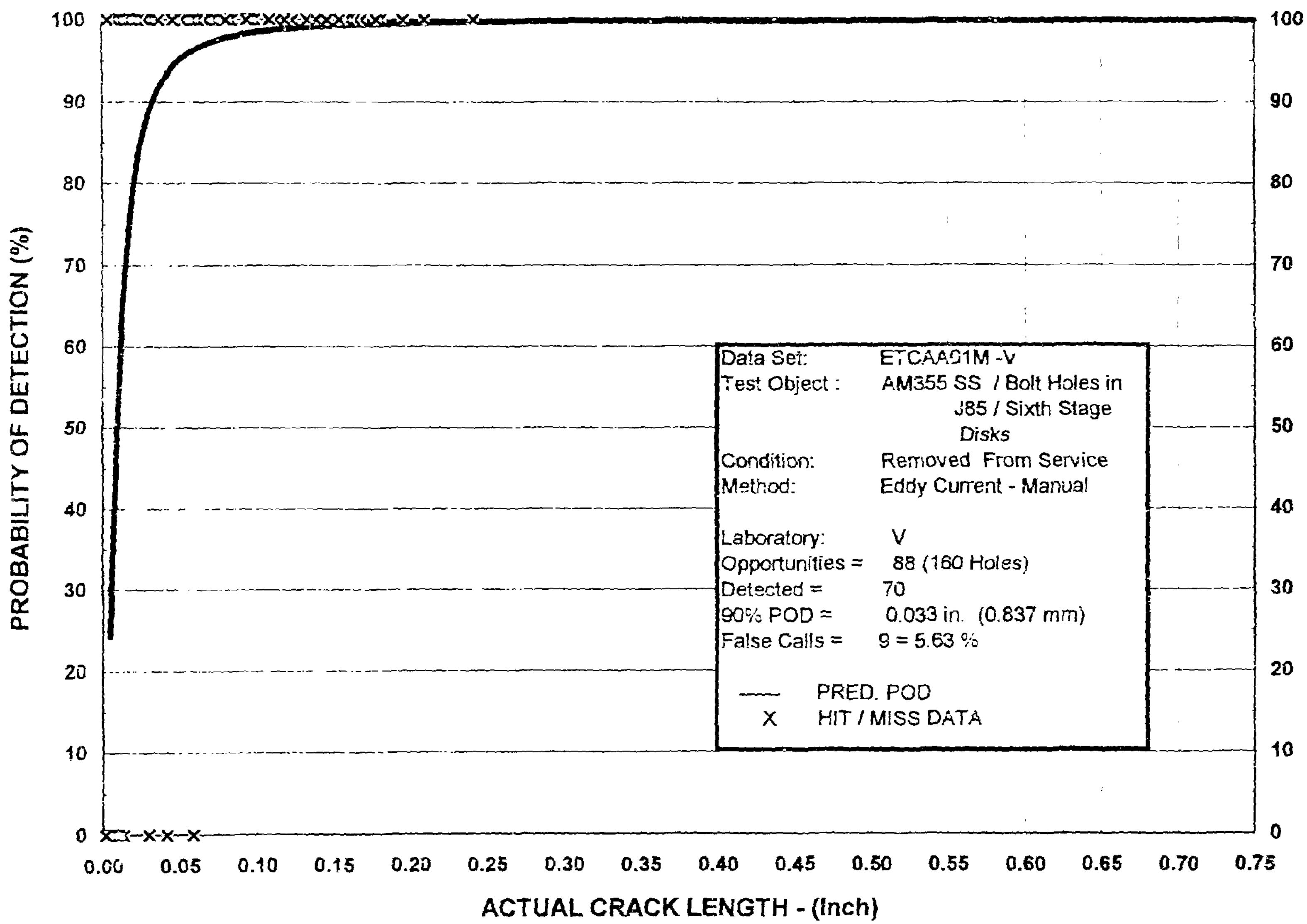


ETCAA01M-I
(ORG. I)

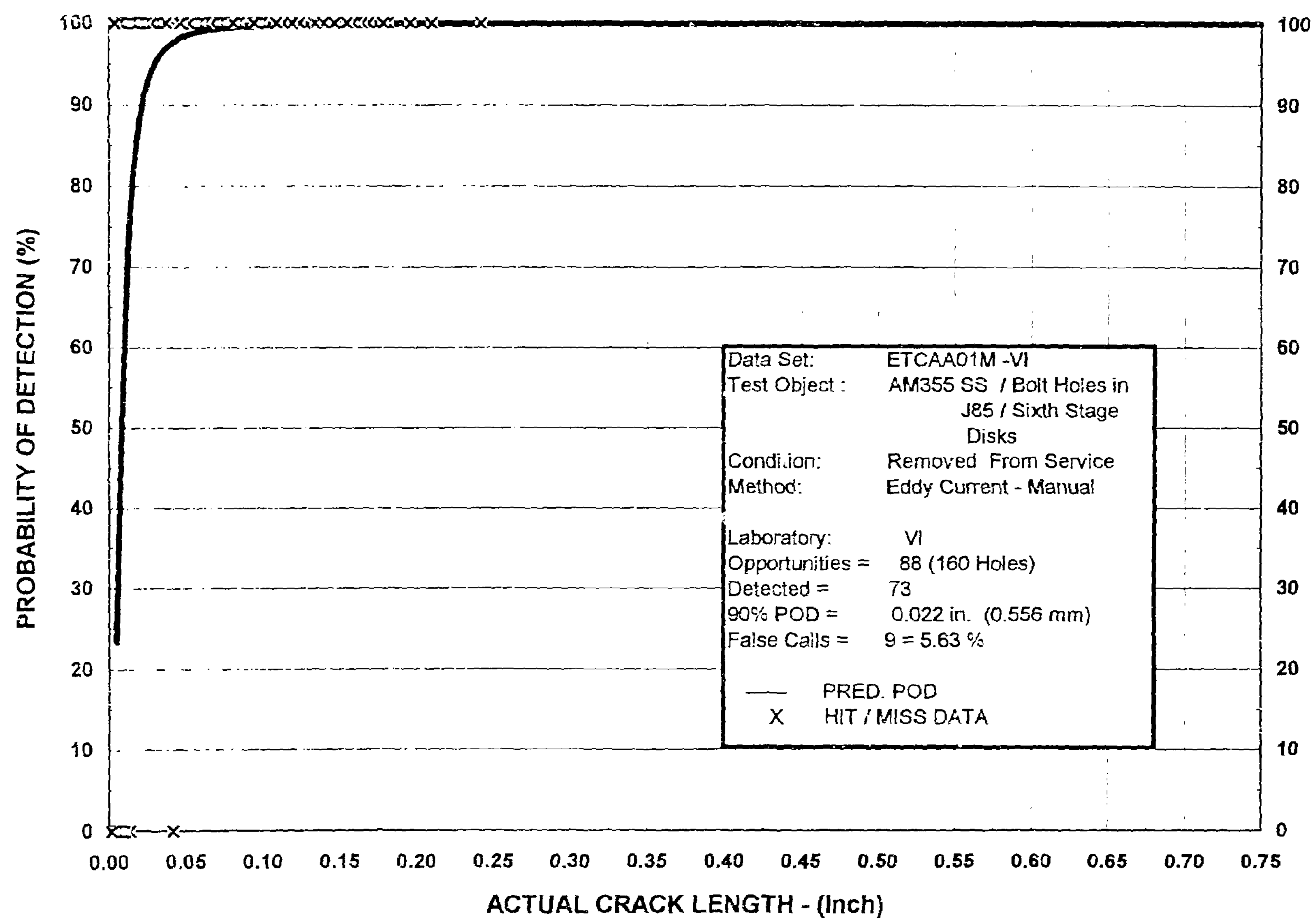


PROBABILITY OF DETECTION (%)
100
90
80
70
60
50
40
30
20
10
0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75
ACTUAL CRACK LENGTH - (Inch)
Data Set: ETCAA01M -III
Test Object : AM355 SS / Bolt Holes in J85 / Sixth Stage Disks
Condition: Removed From Service
Method: Eddy Current - Manual
Laboratory: III
Opportunities = 88 (160 Holes)
Detected = 64
90% POD = 0.036 in. (0.914 mm)
False Calls = 4 = 4.37 %
PRED. POD
X HIT / MISS DATA

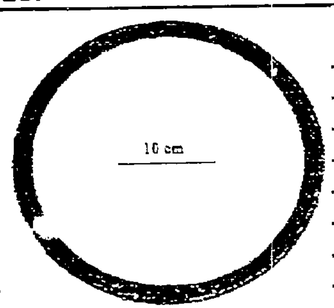

PROBABILITY OF DETECTION (%)
0
10
20
30
40
50
60
70
80
90
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
ACTUAL CRACK LENGTH - (Inch)
Data Set: ETCAA01M -IV
Test Object : AM355 SS / Bolt Holes in J85 / Sixth Stage Disks
Condition: Removed From Service
Method: Eddy Current - Manual
Laboratory: IV
Opportunities = 88 (160 Holes)
Detected = 59
90% POD = 0.091 in. (2.32 mm)
False Calls = 3 = 1.87 %
PRED. POD
X HIT / MISS DATA

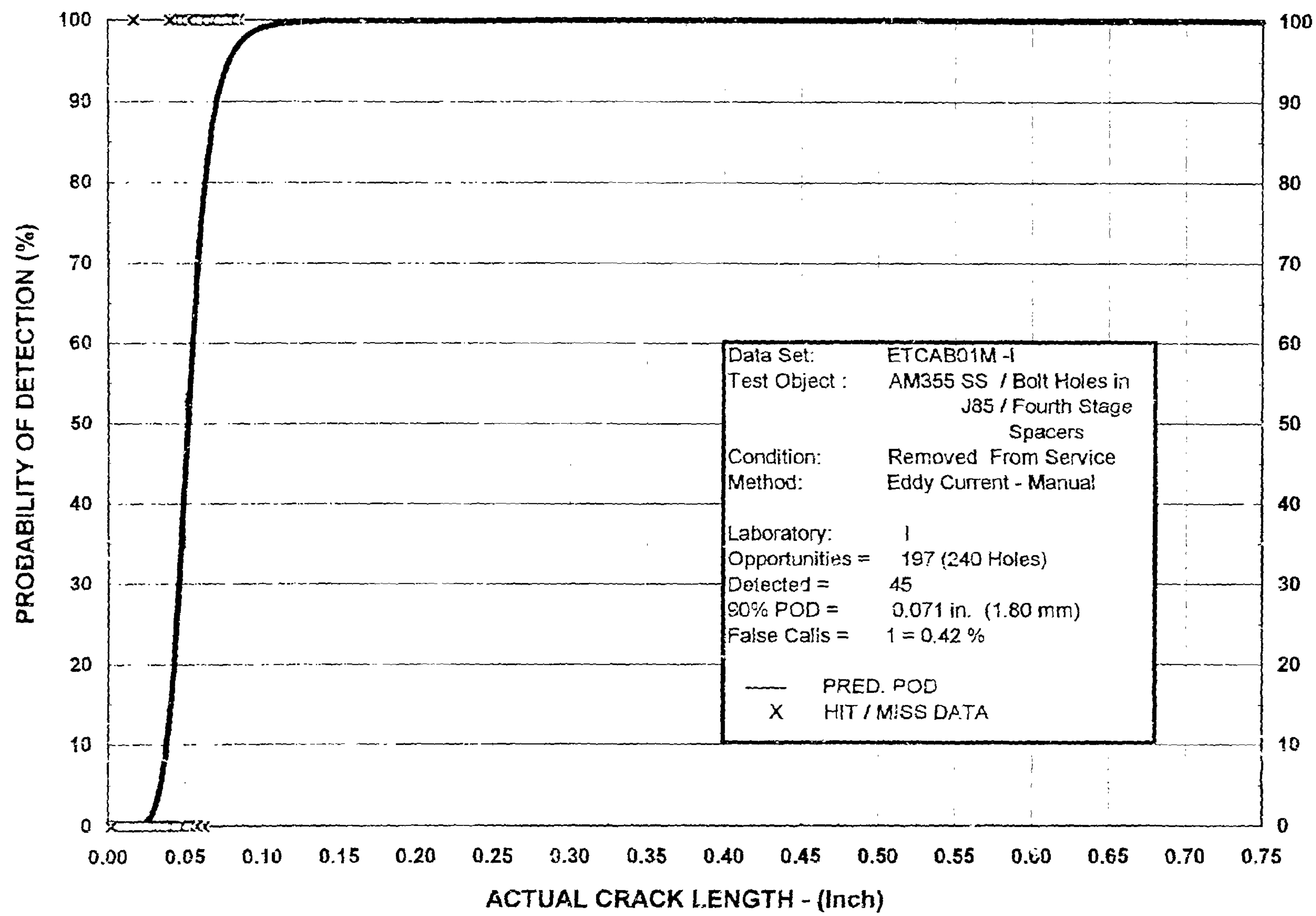


ETCAA01M-V
(ORG. V)



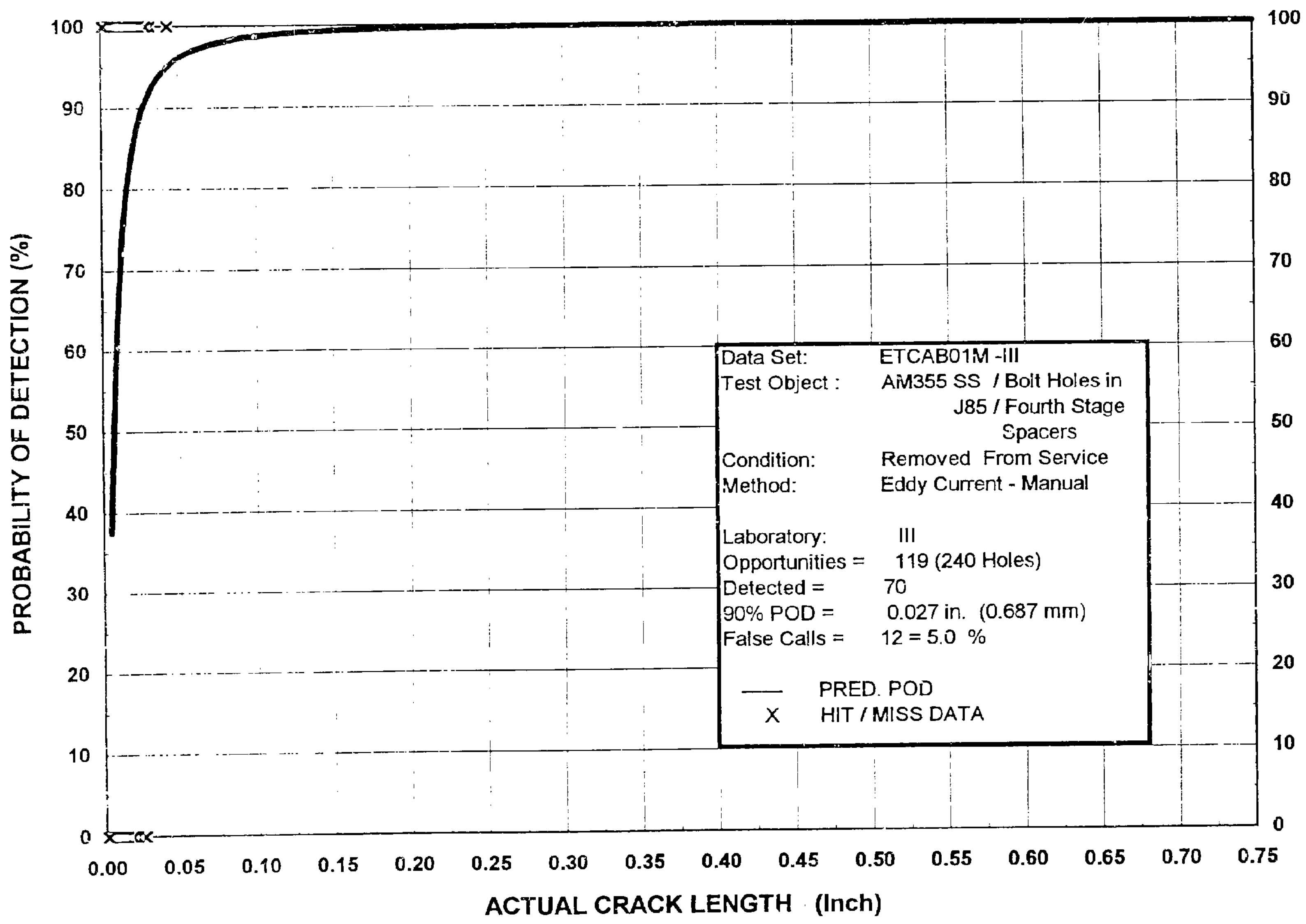
ETCAA01M-VI
(ORG. VI)

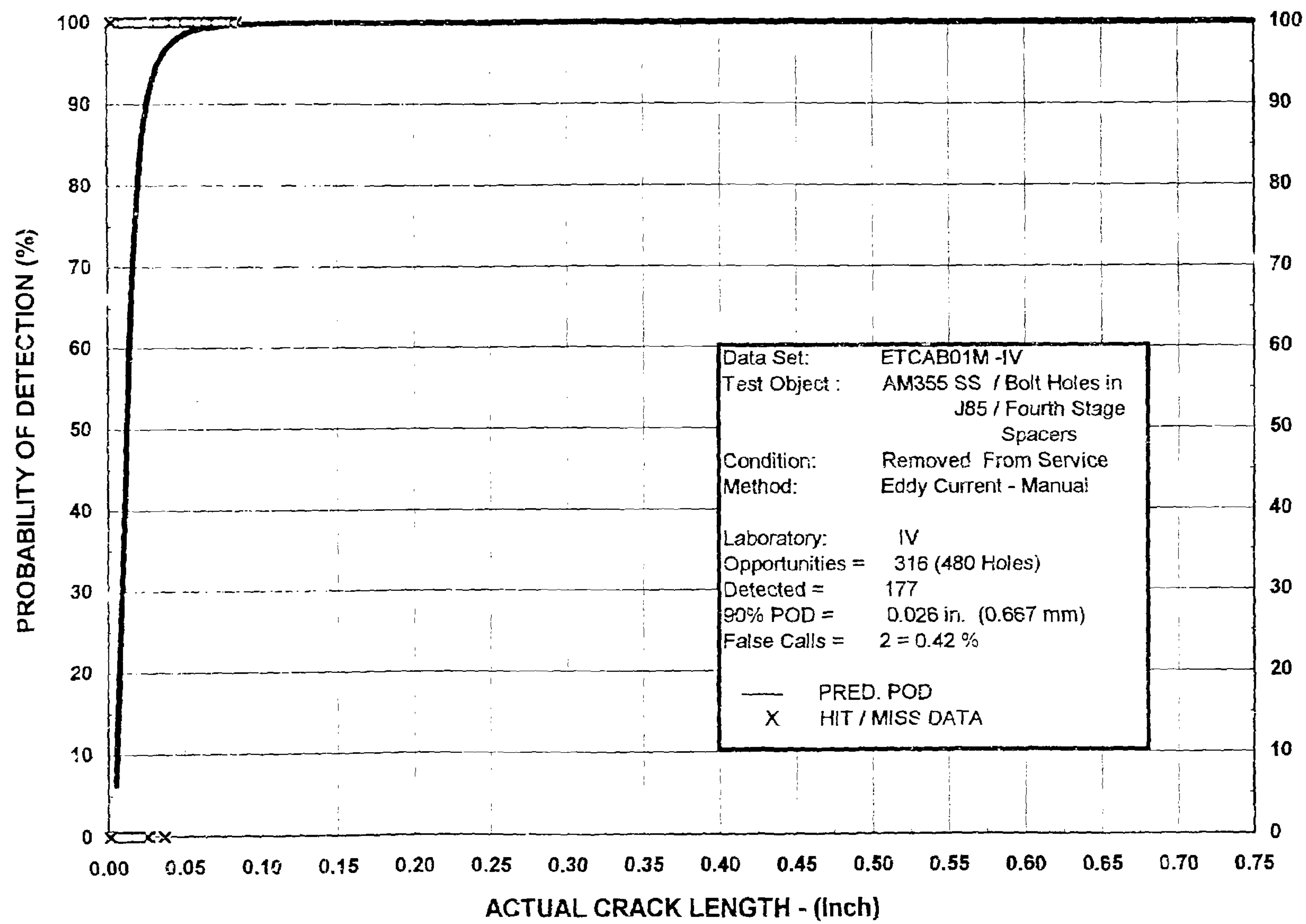
ET- 05 (4)	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Bolt holes in J85 / Fourth stage spacers: 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Eddy current, bolt holes, manual inspection
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	ETCAB01M -I; ETCAB01M -III; ETCAB01M -IV; ETCAB01M -V; AND ETCAB01M -VI
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	I: 240 holes/197 cracks ; III: 240 holes/119 cracks; IV: 480 holes/316 cracks; V: 160 holes/88 cracks; VI: 160 holes/88 cracks
DETECTED:	ORG I: 45; ORG III: 70; ORG IV: 177; ORG V: 70; ORG VI: 77
FALSE CALLS:	ORG I: 1 = 0.42%; ORG III:12 = 5.0% ; ORG IV: 2 = 0.42 %; ORG V:9 = 5.6%; ORG VI: 1 = 0.625%
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG I: 0.071 in. (1.80mm)
	ORG III: 0.027 in. (0.687mm)
	ORG IV: 0.026 in. (0.667mm)
	ORG V: 0.033 in. (0.837mm)
	ORG VI: 0.028 in. (0.625mm)



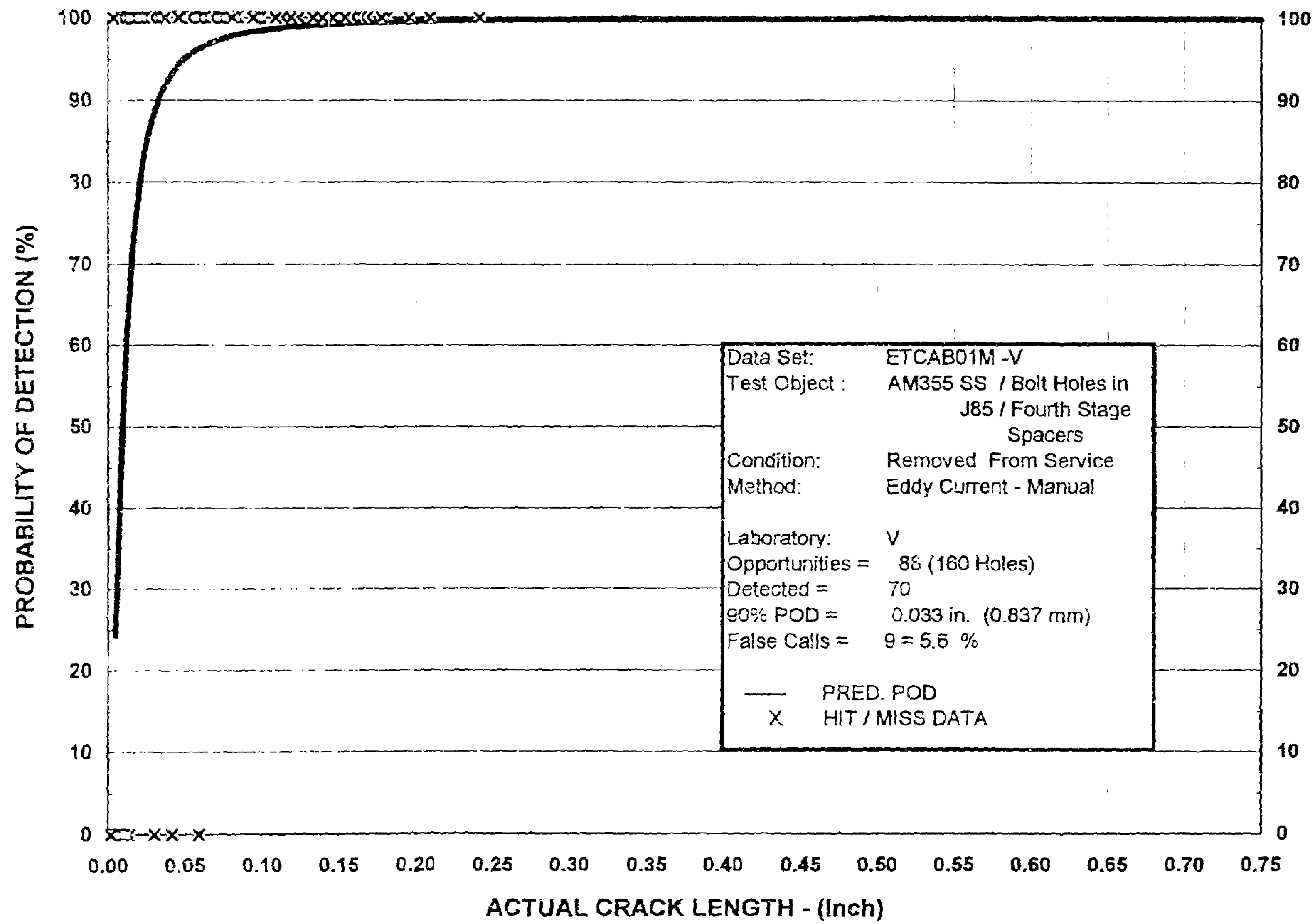
ET-05 (4)
6/95

ETCAB01M-I
(ORG. I)

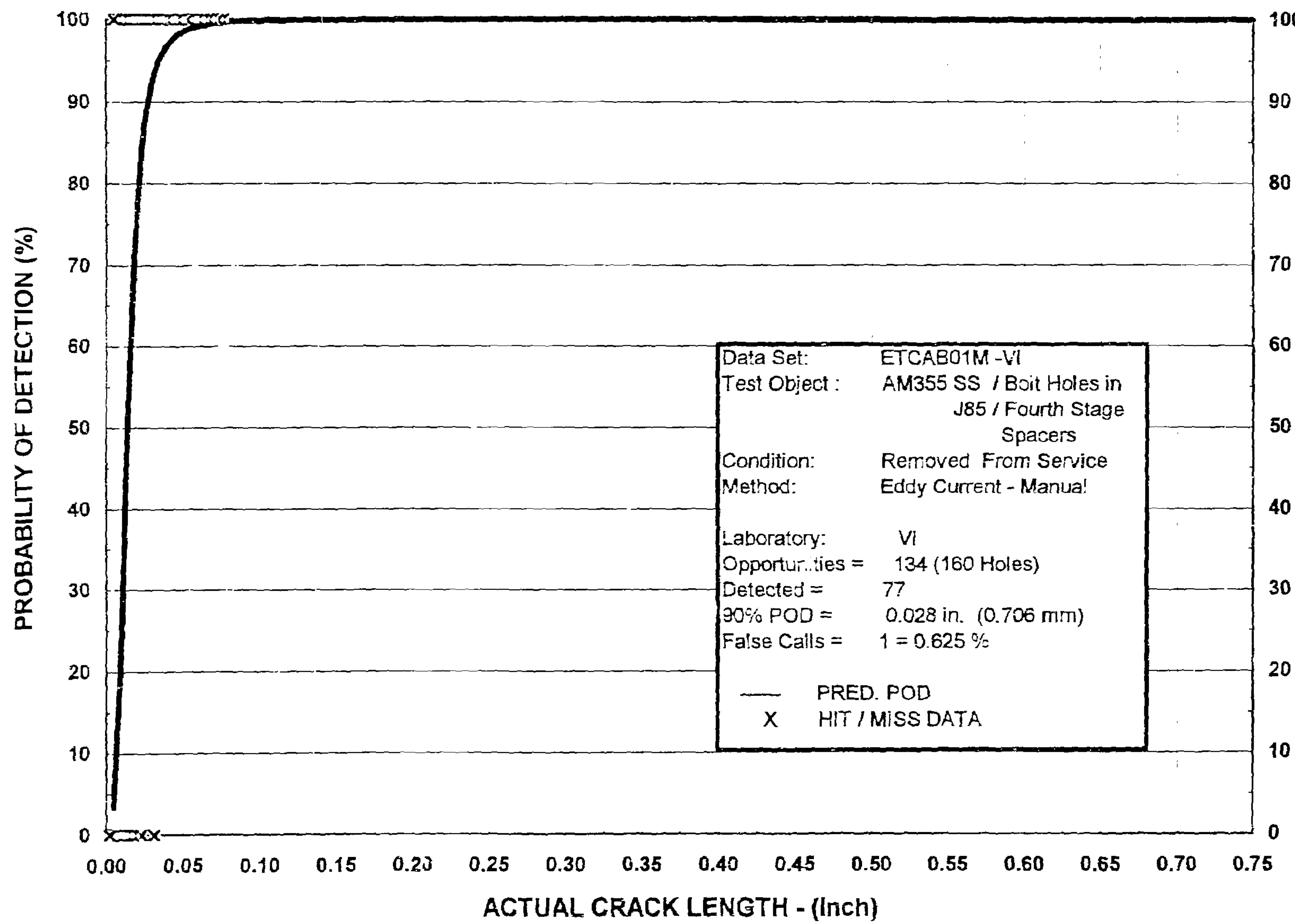

PROBABILITY OF DETECTION (%)
100
90
80
70
60
50
40
30
20
10
0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75
ACTUAL CRACK LENGTH (Inch)
Data Set: ETCAB01M -III
Test Object : AM355 SS / Bolt Holes in J85 / Fourth Stage Spacers
Condition: Removed From Service
Method: Eddy Current - Manual
Laboratory: III
Opportunities = 119 (240 Holes)
Detected = 70
90% POD = 0.027 in. (0.687 mm)
False Calls = 12 = 5.0 %
PRED. POD
X HIT / MISS DATA



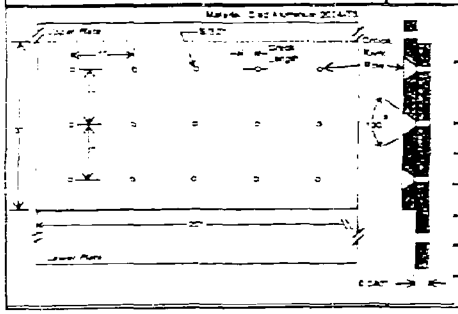
ETCAB01M-IV
(ORG. IV)

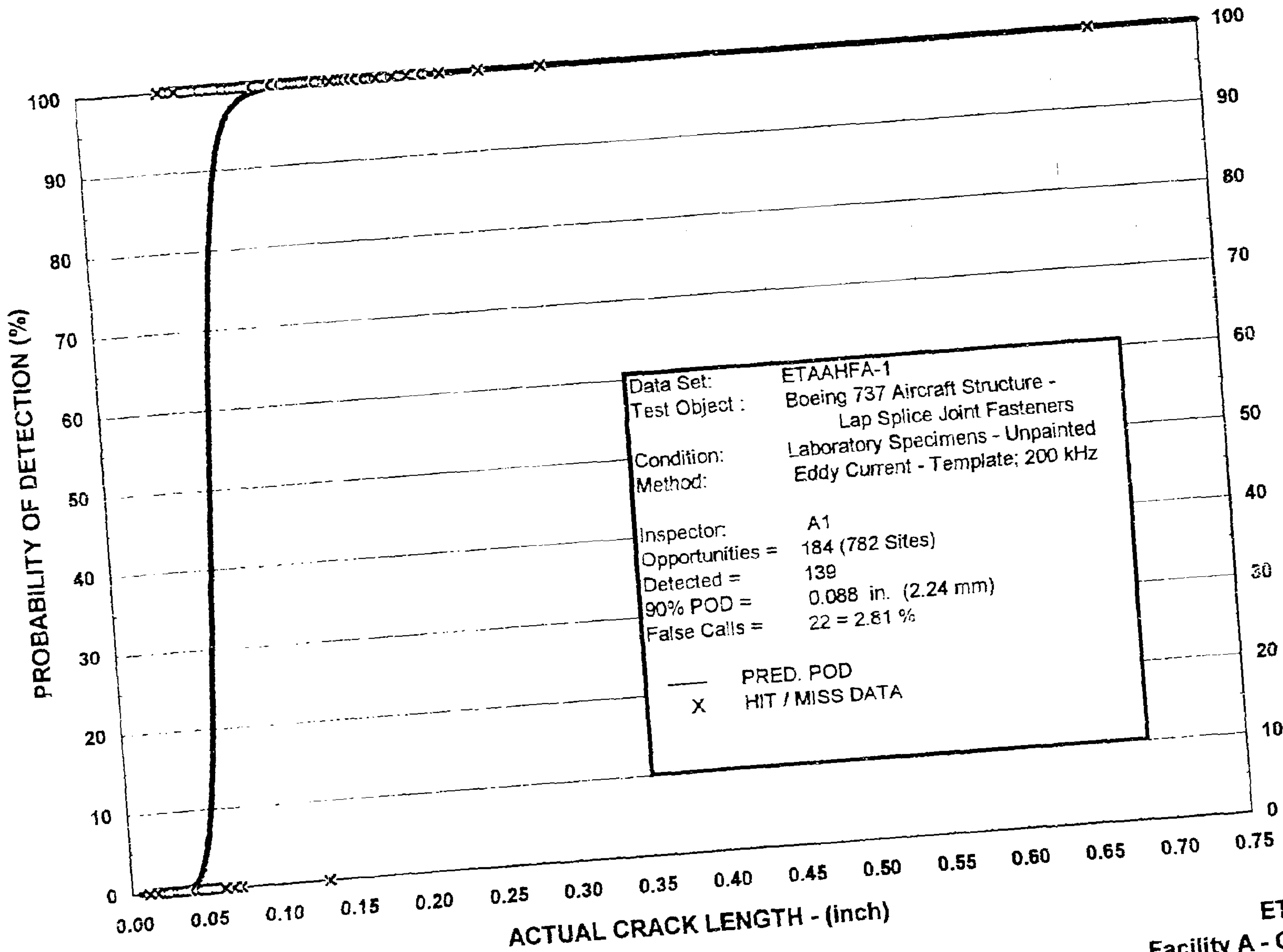


ETCAB01M-V
(ORG. V



ETCAB01M-VI
(ORG. VI)

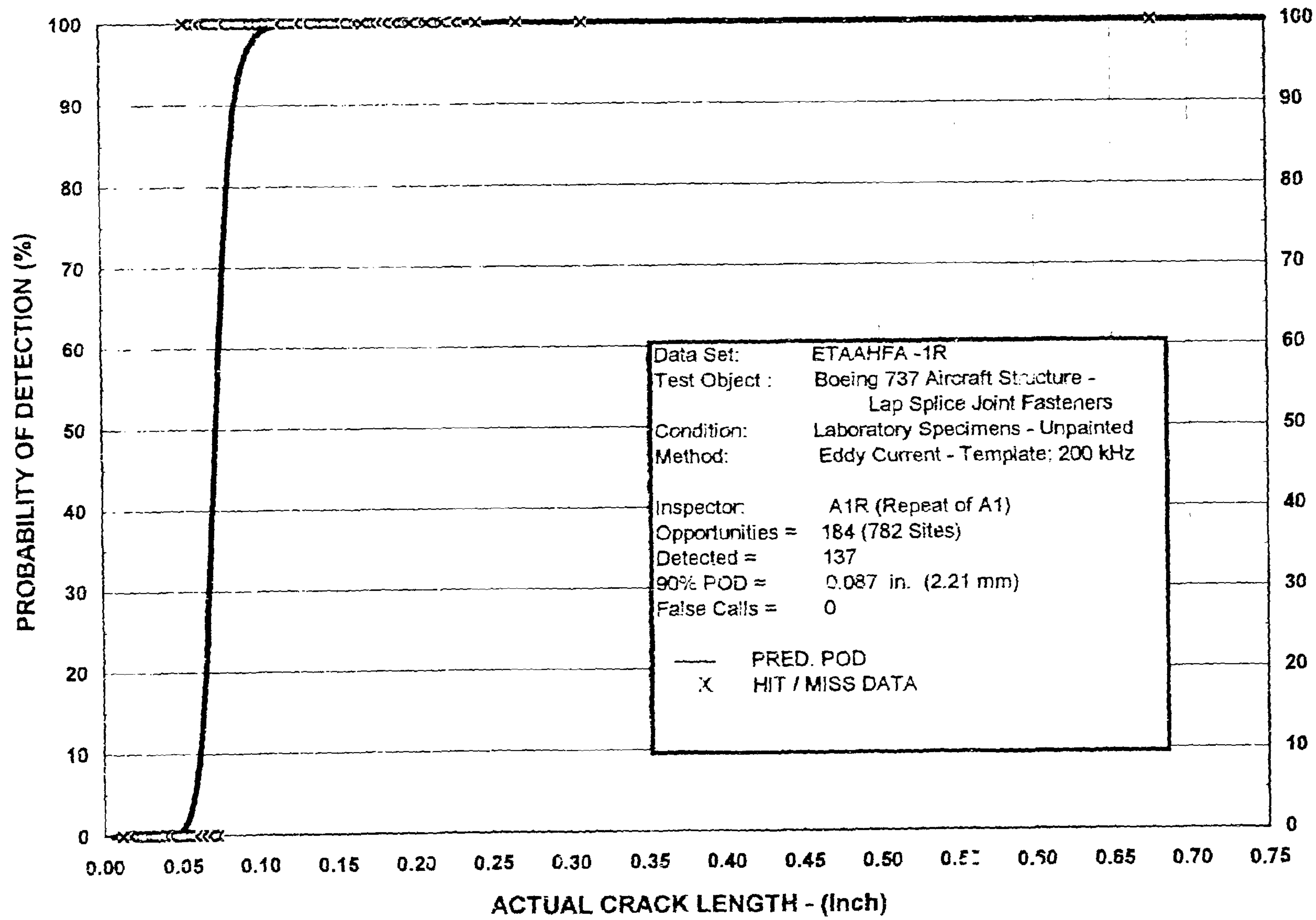
ET-06 (5)A CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Contract Probe at 200 kHz (NDT-19)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ———— **UNPAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a template ———— NOTE: Manual scan with a template is the "Calibration at 0.100" recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAFO1A-1; A-1R; A-2; A-3, and A-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	A1= 139; A1R= 139; A2= 146; A3= 144; A4= 143
FALSE CALLS:	A1, 22 = 2.81%; A1R, 0; A2, 0; A3.0; A4, 3 = 0.38%
REFERENCE:	DOT/FAA/CT-92/12.III Spencer, Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.
	The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.
	The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]
	90% POD Length - "AS PRODUCED"
	A1= 0.088 in. (2.24 mm)
	A1R= 0.087 in. (2.21 mm)
	A2= 0.071 in. (1.80 mm)
	A3= 0.081 in. (2.07 mm)
	A4= 0.079 in. (2.00 mm)



ETAAHFA-1
Facility A - Operator 1

ET - 06 (5) A LAP SPLICE JOINT INSPECTION

6/95

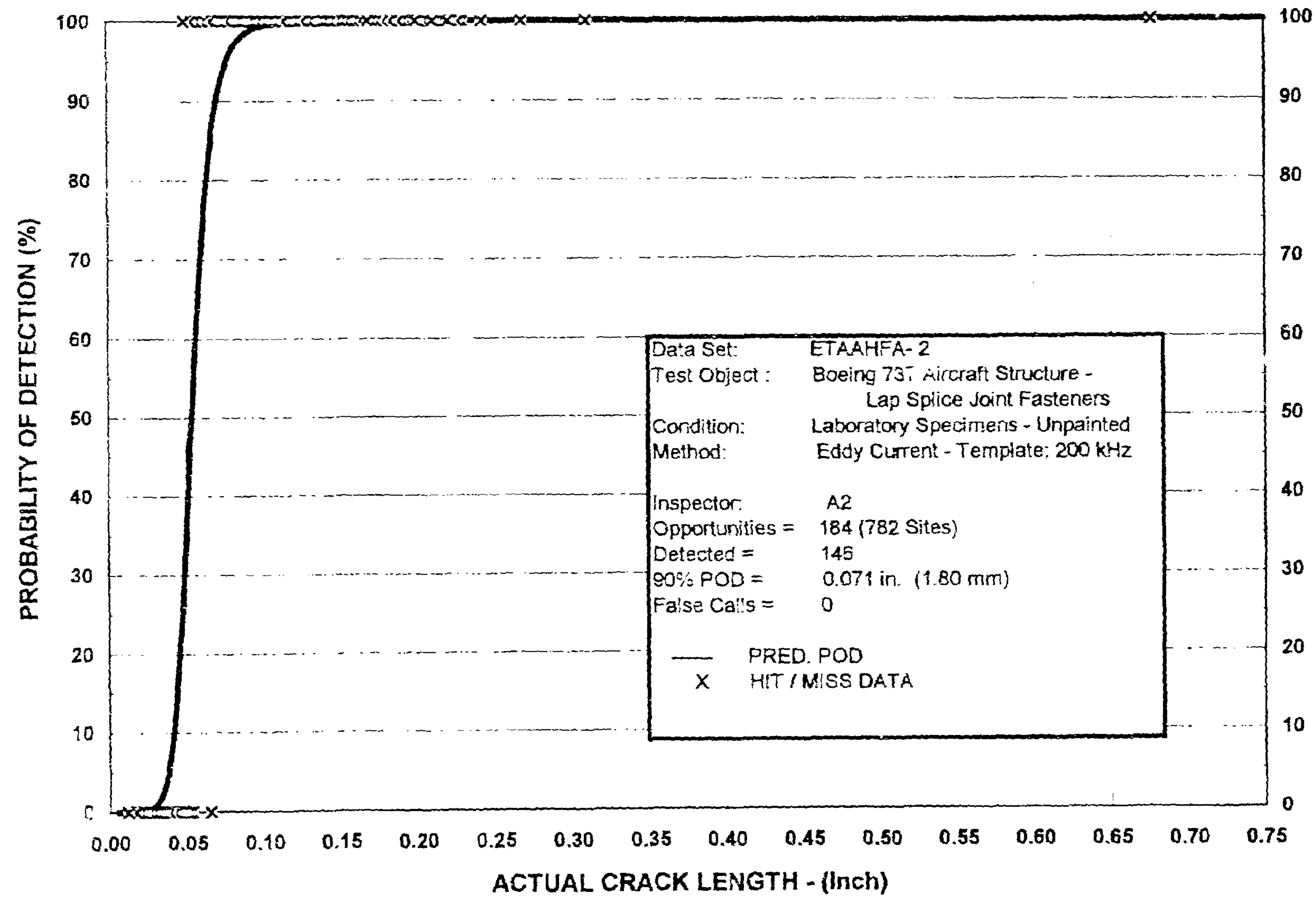


ET - 06 (5) A LAP SPLICE JOINT INSPECTION

6/95

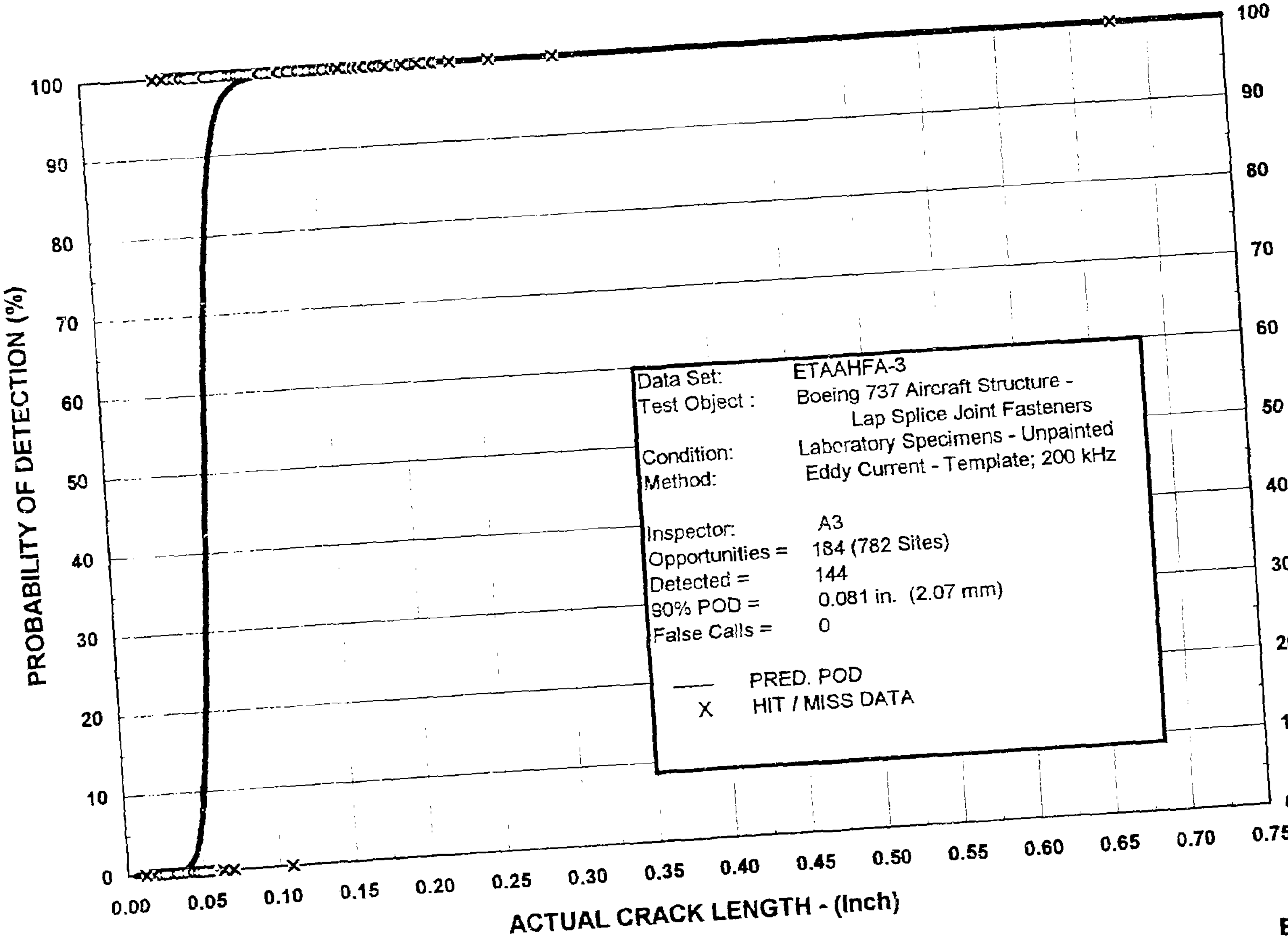
ETAAHFA-1R

Facility A - Operator 1 / REPEAT



ETAAHFA-2
Facility A - Operator 2

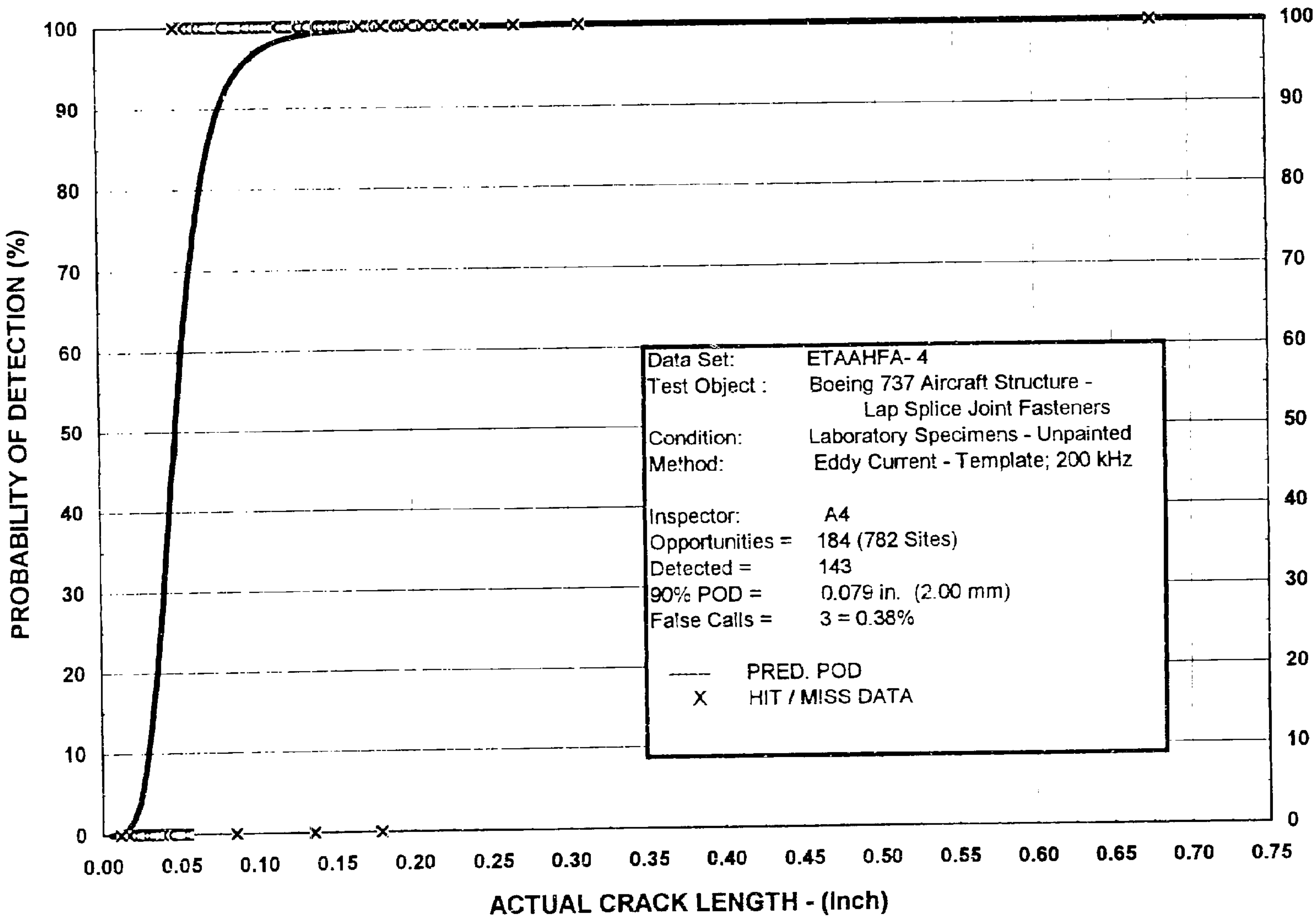
ET - 06 (5)A LAP SPLICE JOINT INSPECTION
6/95



ETAAHFA-3
Facility A - Operator 3

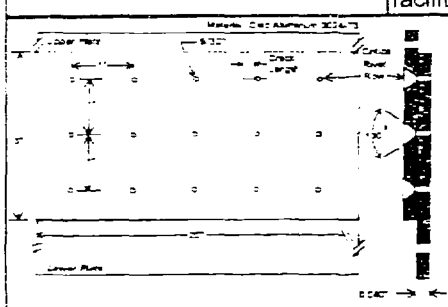
ET - 06 (5)A LAP SPLICE JOINT INSPECTION

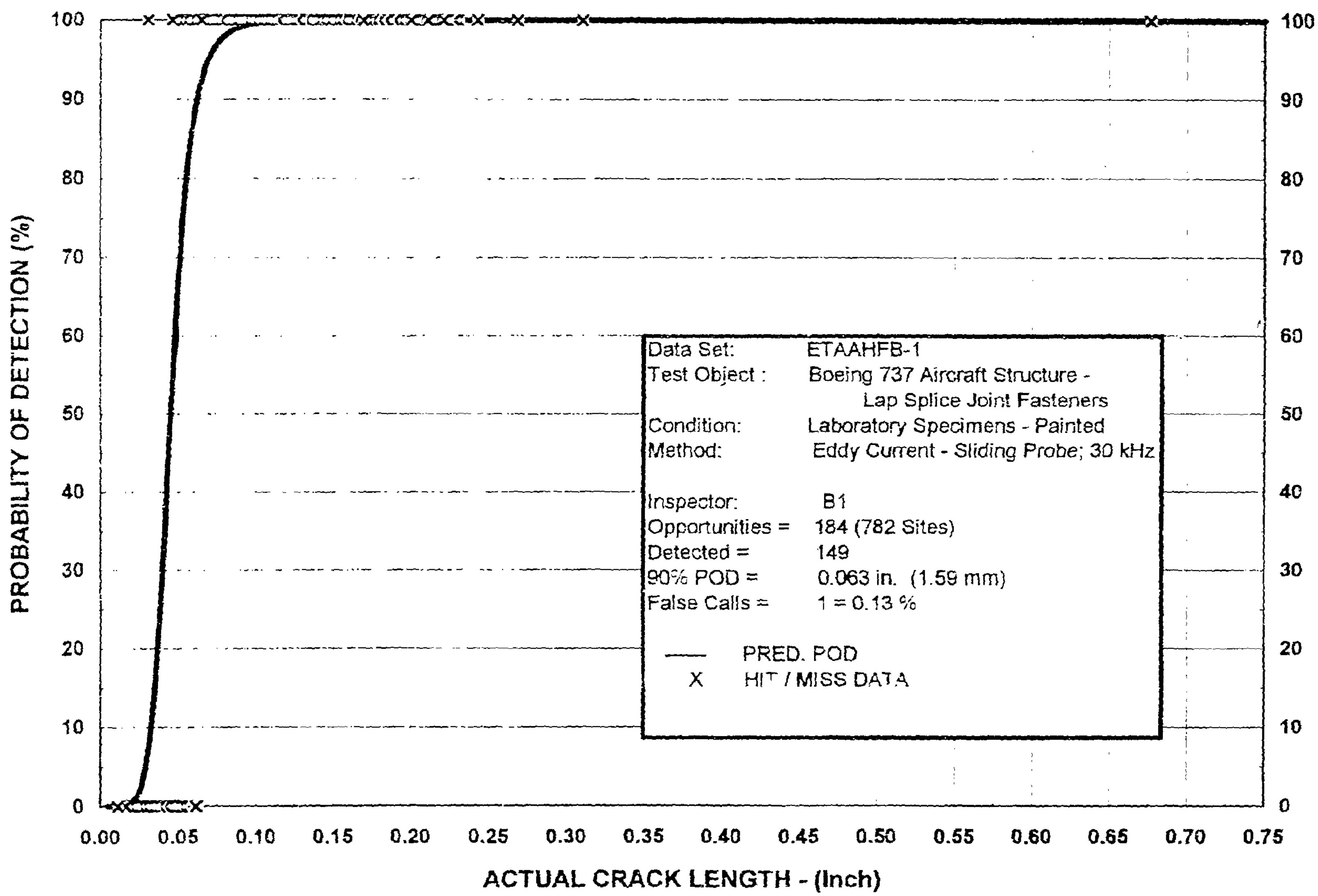
6/95



ETAAHFA-4
Facility A - Operator 4

ET - 06 (5)A LAP SPLICE JOINT INSPECTION
6/95

ET-06 (5)B,CRACK LENGTH	**DATA SET DESCRIPTION**
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Sliding Probe at 30 kHz. (NDT-19)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick. lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ---------------**PAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual sliding probe** --------------------**NOTE: Manual scan with a template is the** **"Calibration at 0.100"** **recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAHFB-1: B-2: B-3. B-4 and B-4R
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	B1= 149; B2= 151; B3= 129; B4= 136; B4R= 144
FALSE CALLS:	B1.1= 0.13%; B2. 1 = 0.13%; B3.2 = 0.26%; B4.0; B4R.0
REFERENCE:	DOT/FAA/CT-92/12.III Spencer. Floyd and Donald Schurman. **<u>Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment</u>**. *May 1995*
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith. FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Alb:querque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.
	The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.
	The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]
	90% POD Length - "AS PRODUCED"
	B1= 0.063 in. (1.59 mm)
	B2= 0.097 in. (2.47 mm)
	B3= 0.081 in. (2.06 mm)
	B4= 0.092 in. (2.37 mm)
	B4R= 0.070 in. (1.77 mm)

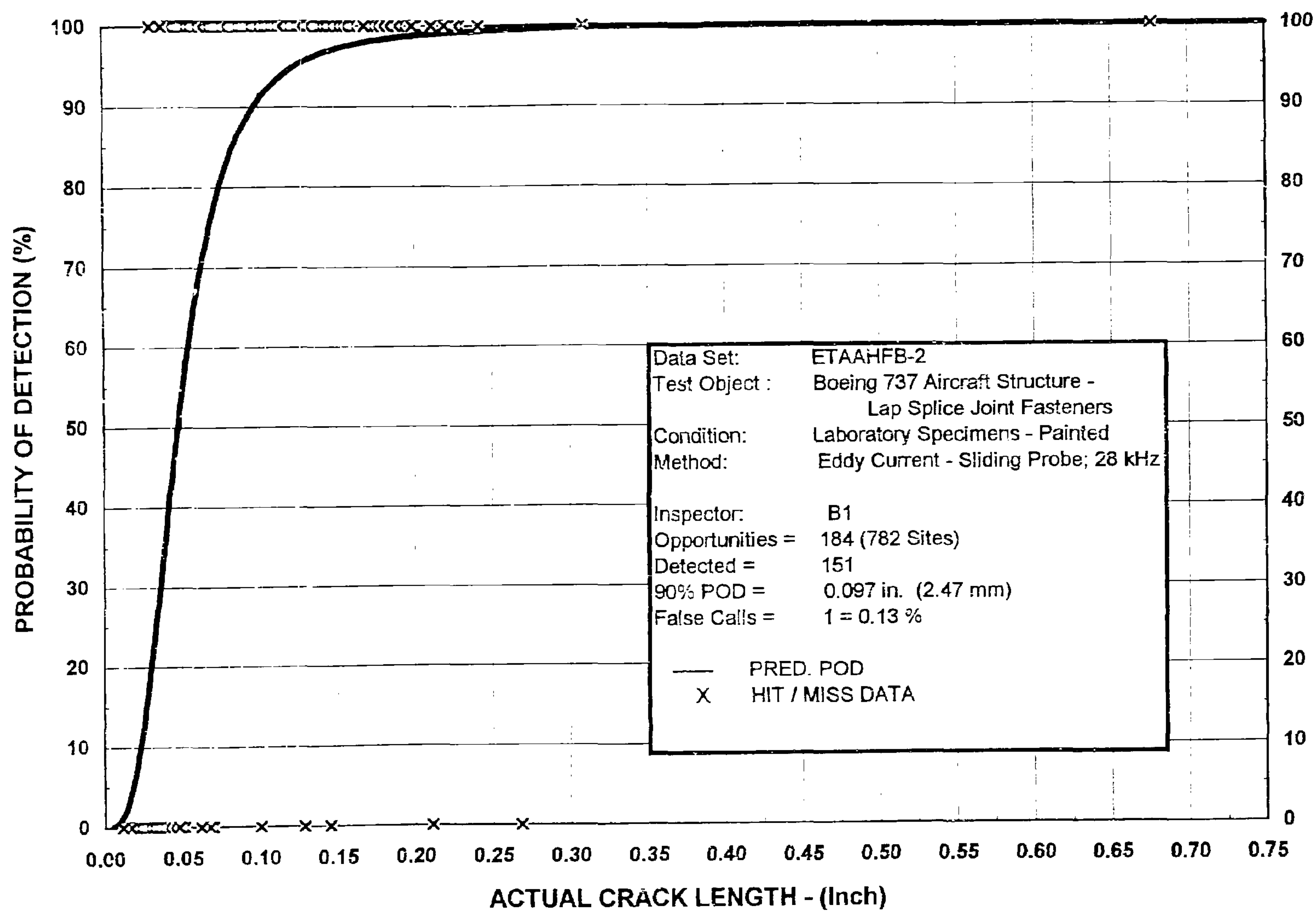


ET - 06 (5)B LAP SPLICE JOINT INSPECTION

06/95

ETAAFH1B-1

Facility B - Operator 1

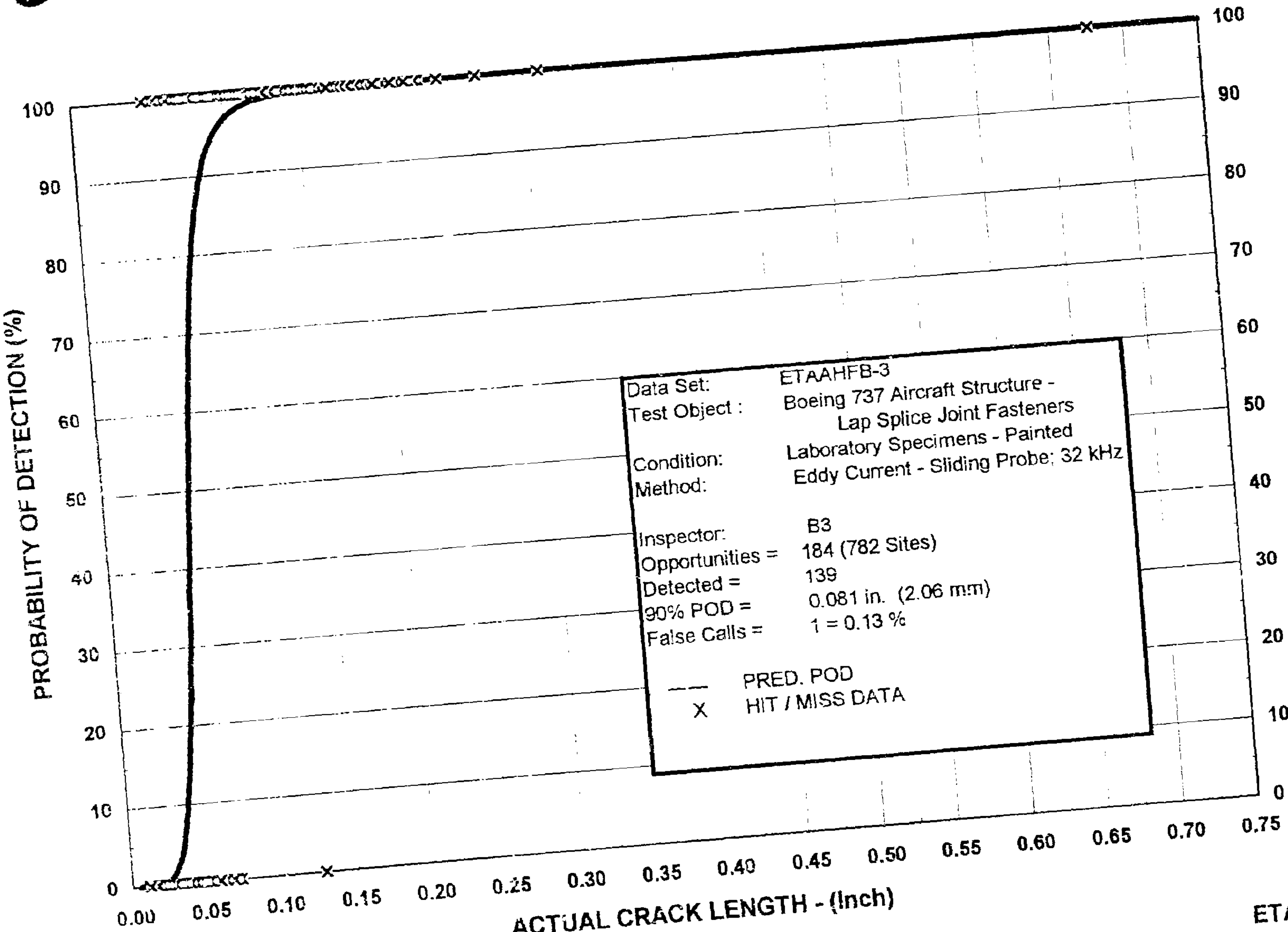


ETAAHFB-2

Facility B - Operator 2

ET - 06 (5)B LAP SPLICE JOINT INSPECTION

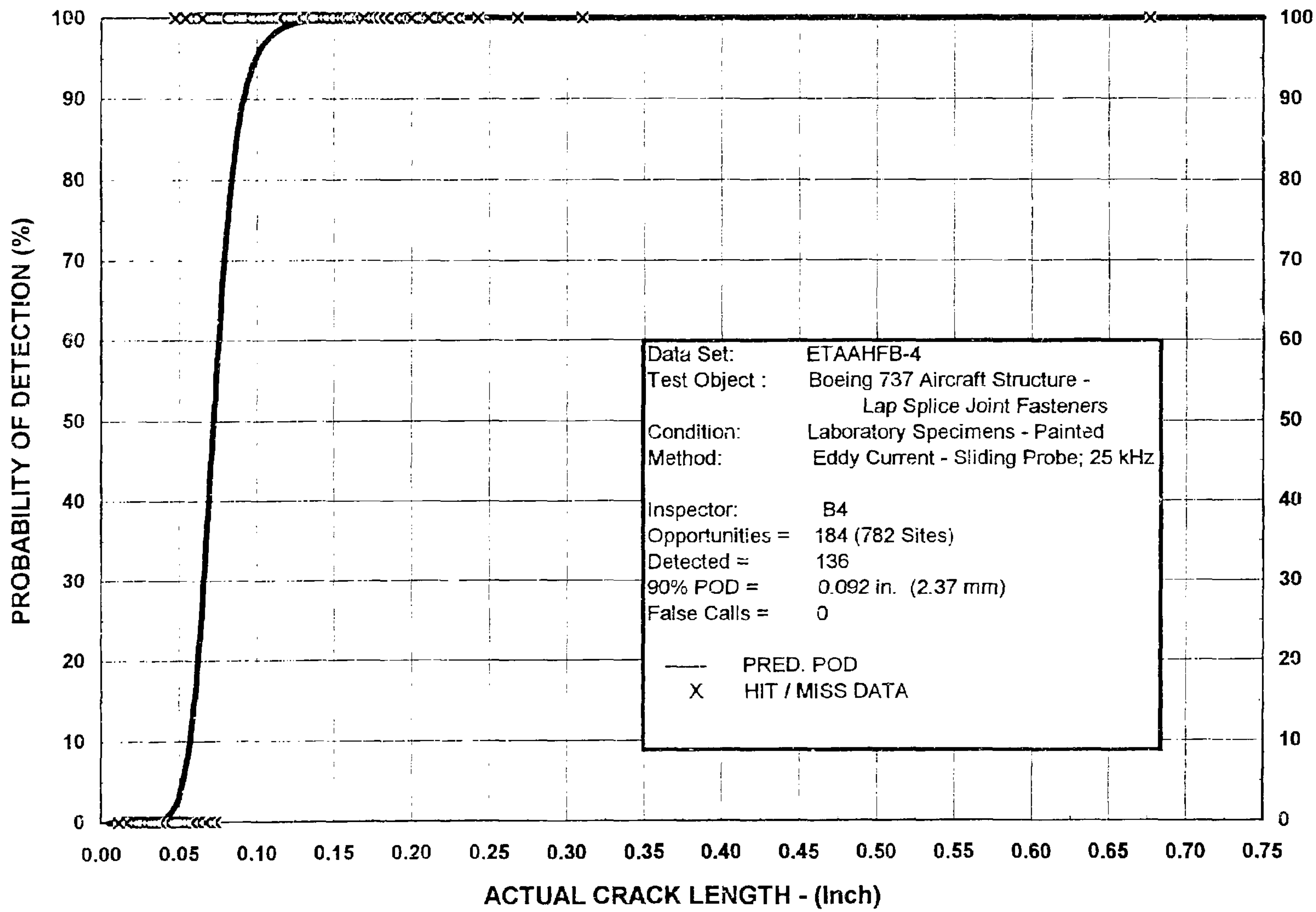
06/95



ETAAHF1B-3
Facility B - Operator 3

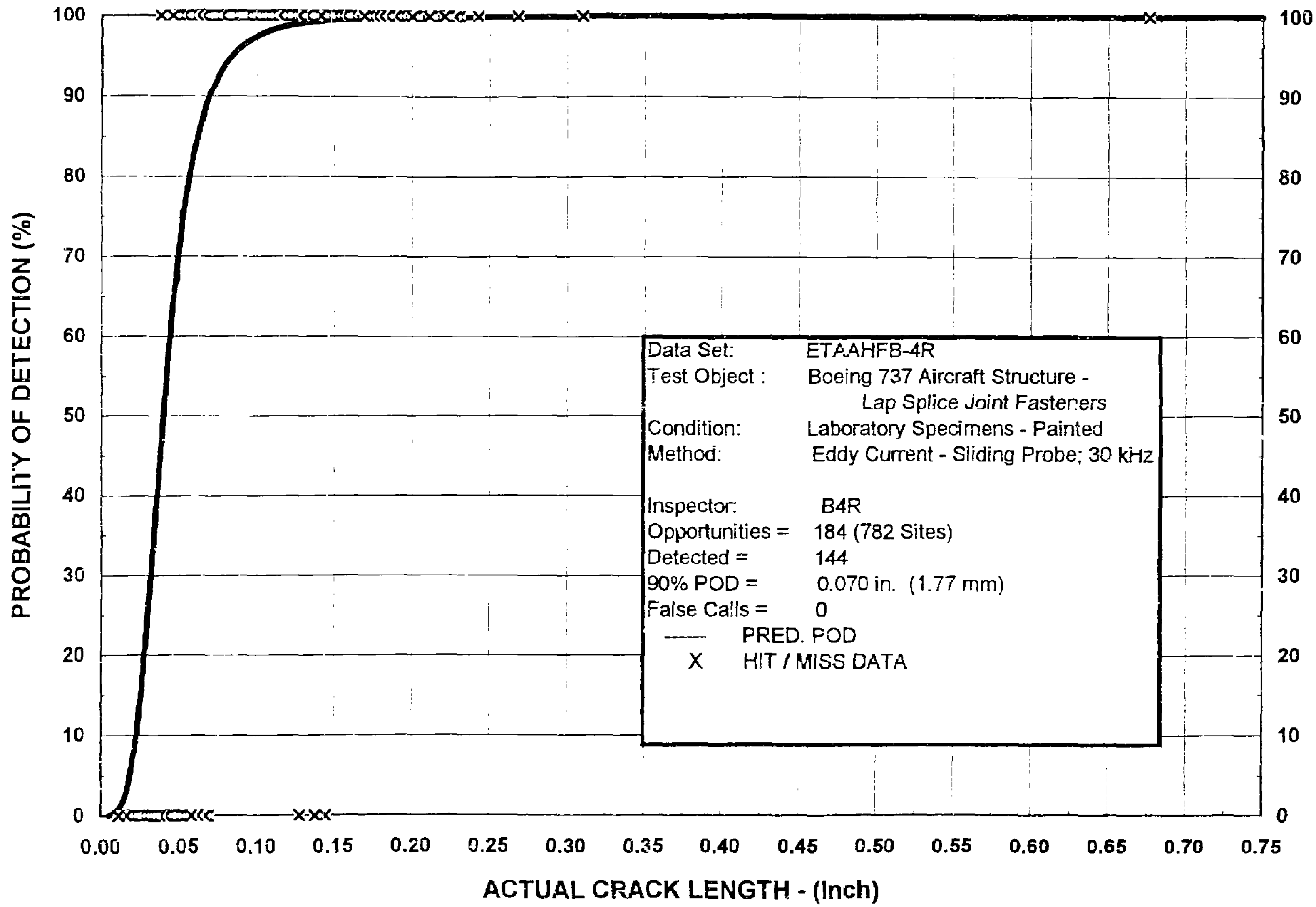
ET - 06 (5)B LAP SPLICE JOINT INSPECTION

6/95



ETAAHFB-4
Facility B - Operator 4

ET - 06 (5)B LAP SPLICE JOINT INSPECTION
06/95

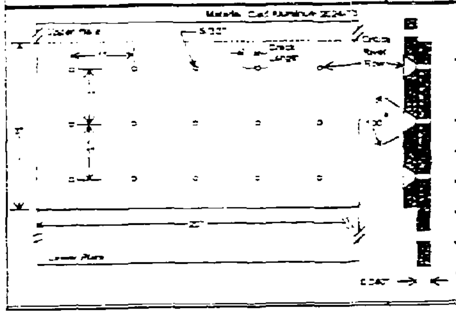


ETAAHFB-4R
Facility B - Operator 1 /REPEAT

ET - 06 (5)B LAP SPLICE JOINT INSPECTION

06/95

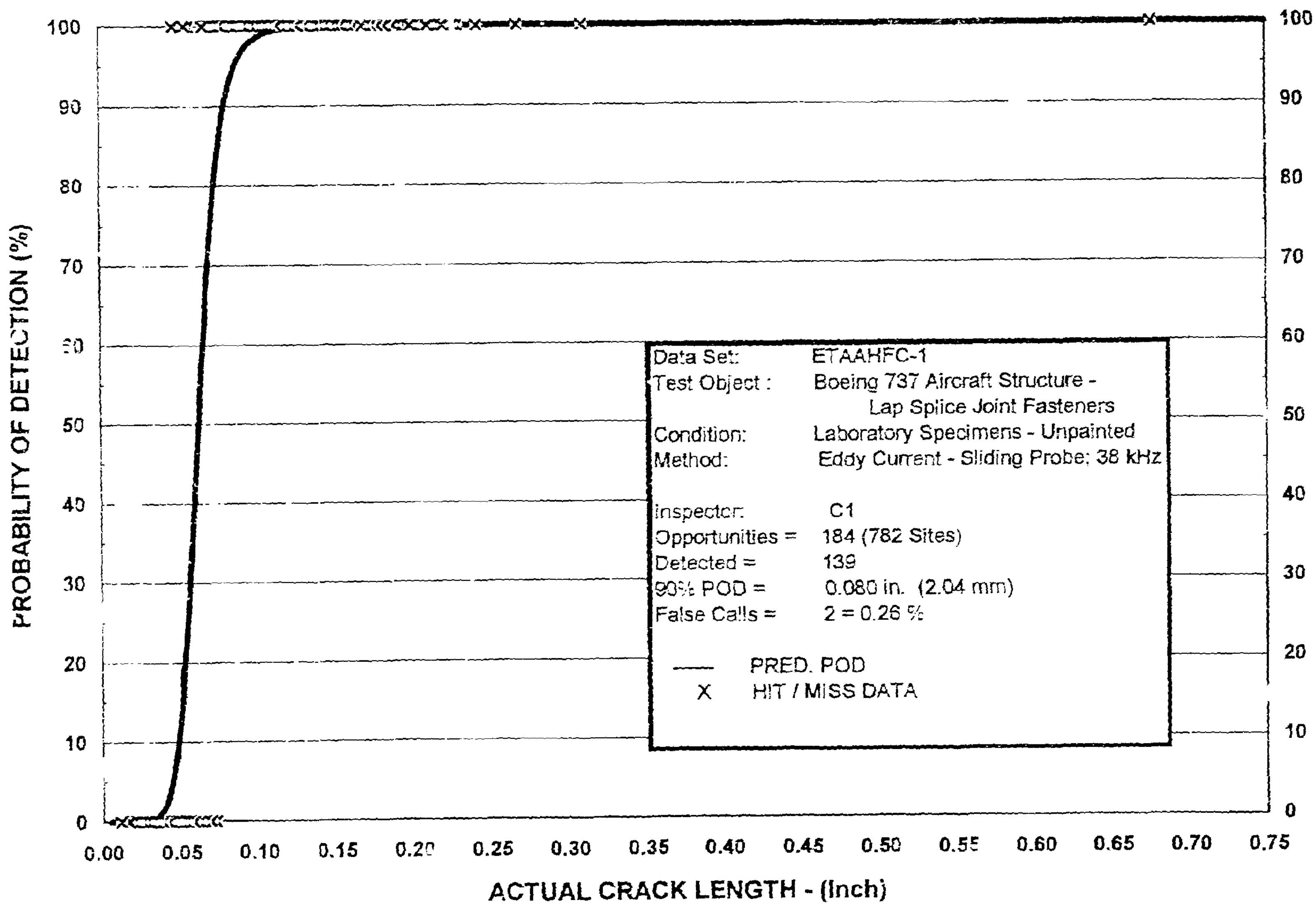
ET-06 (5)C, CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Sliding Probe at 38 kHz. (NDT-19)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**UNPAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a sliding probe————NOTE: Manual scan with a template is the "Calibration at 0.100" recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAFHC-1 ; C-2: C-3. C-4 and C-4R
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	C-1 = 139; C-2 = 146; C-3 = 153, C-4 = 106 and C-4R = 119
FALSE CALLS:	C-1,2 = 0.26% ; C-2,1 = 0.13%; C-3,6 = 0.79%, C-4,1 = 0.13% and C-4R,0
REFERENCE:	DOT/FAA/CT-92/12,III Spencer. Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.



The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.

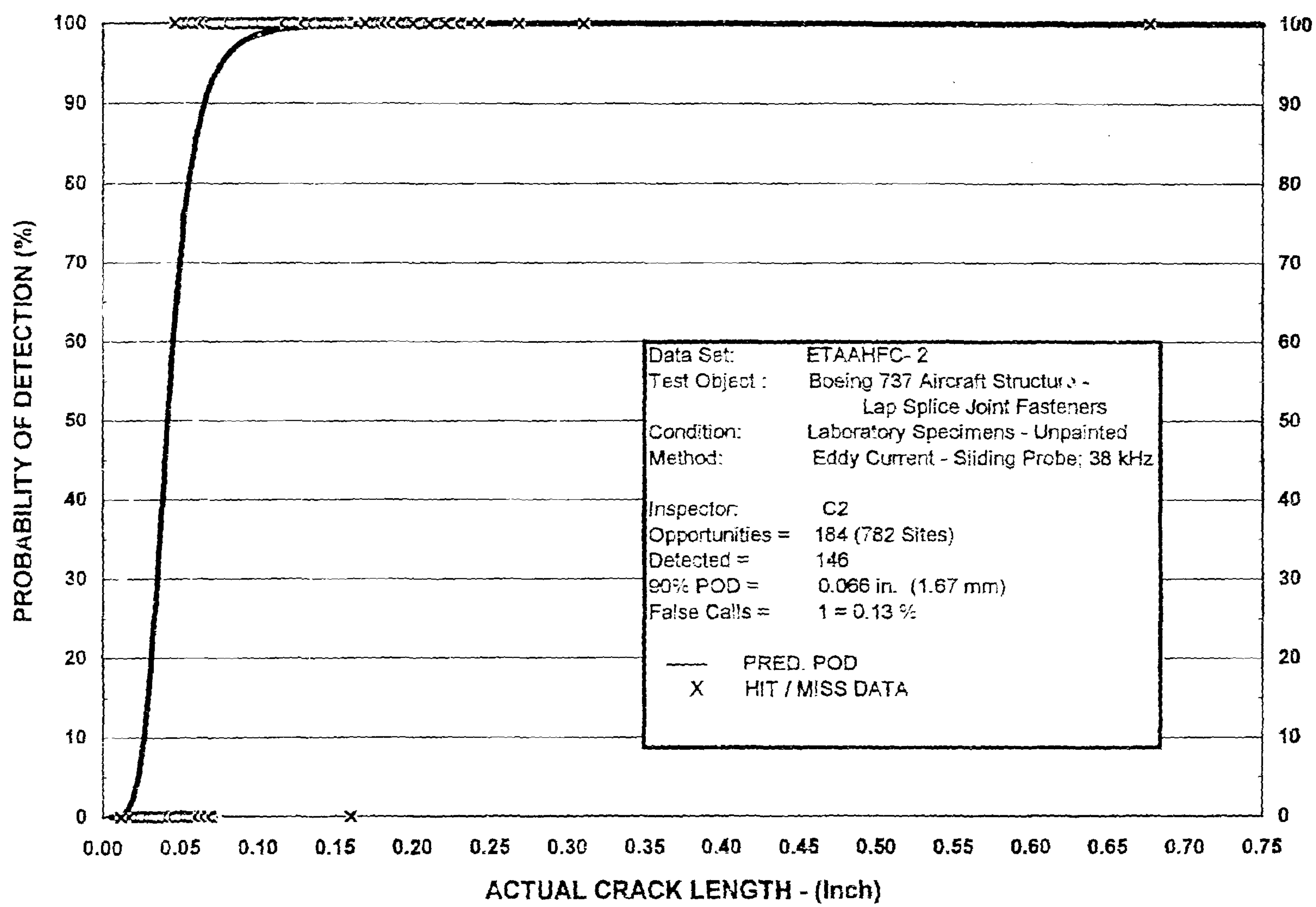
The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]

90% POD Length -	"AS PRODUCED"
C1= 0.080 in.	(2.04 mm)
C2= 0.066 in.	(1.67 mm)
C3= 0.065 in.	(1.65 mm)
C4= 0.140 in.	(3.55 mm)
C4R= 0.126 in.	(3.21 mm)



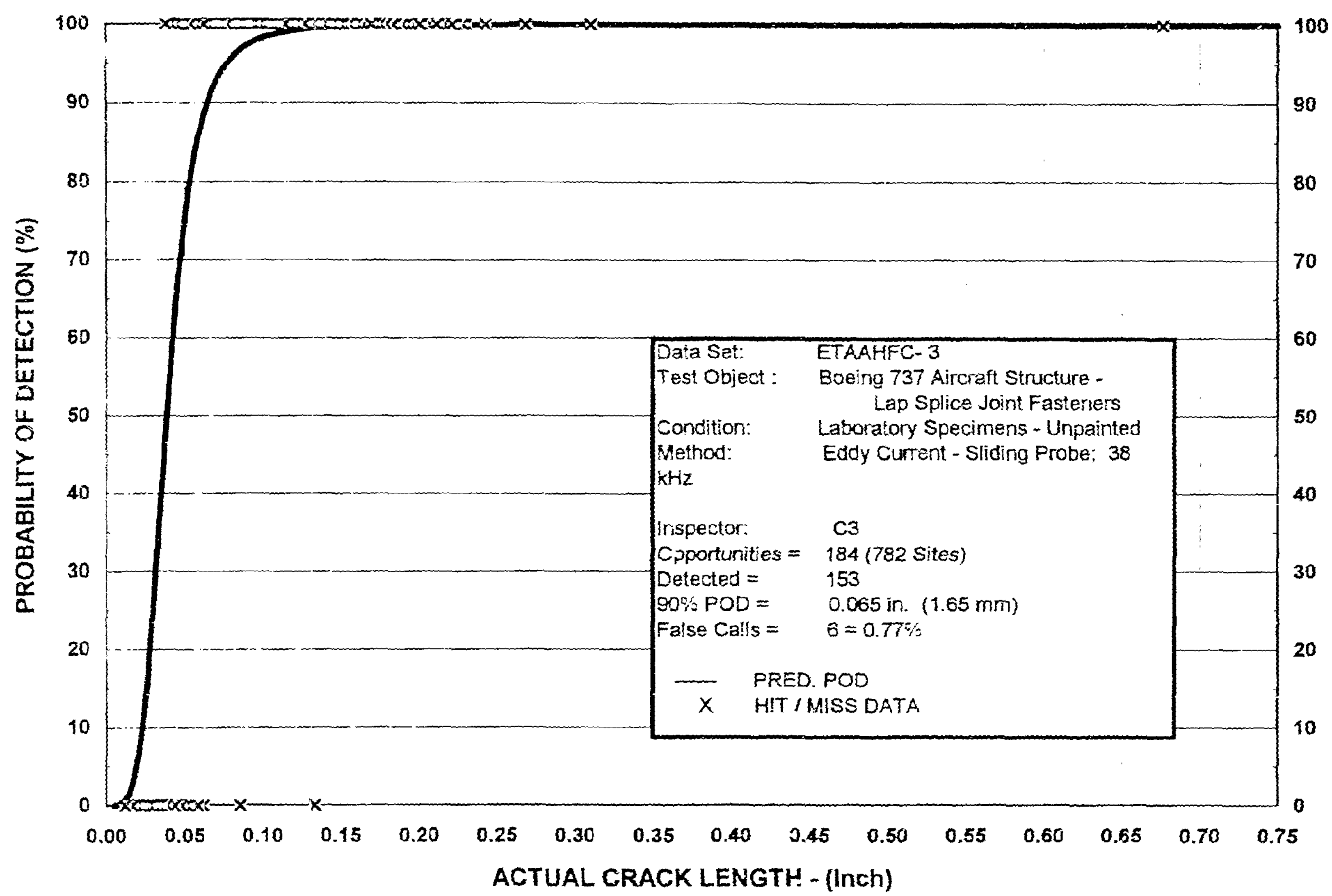
ETAAHFC-1
Facility C - Operator 1

ET - 06 (5)C LAP SPLICE JOINT INSPECTION
06/95



ETAAHFC-2
Facility C - Operator 2

ET - 06 (5)C LAP SPLICE JOINT INSPECTION
06/95

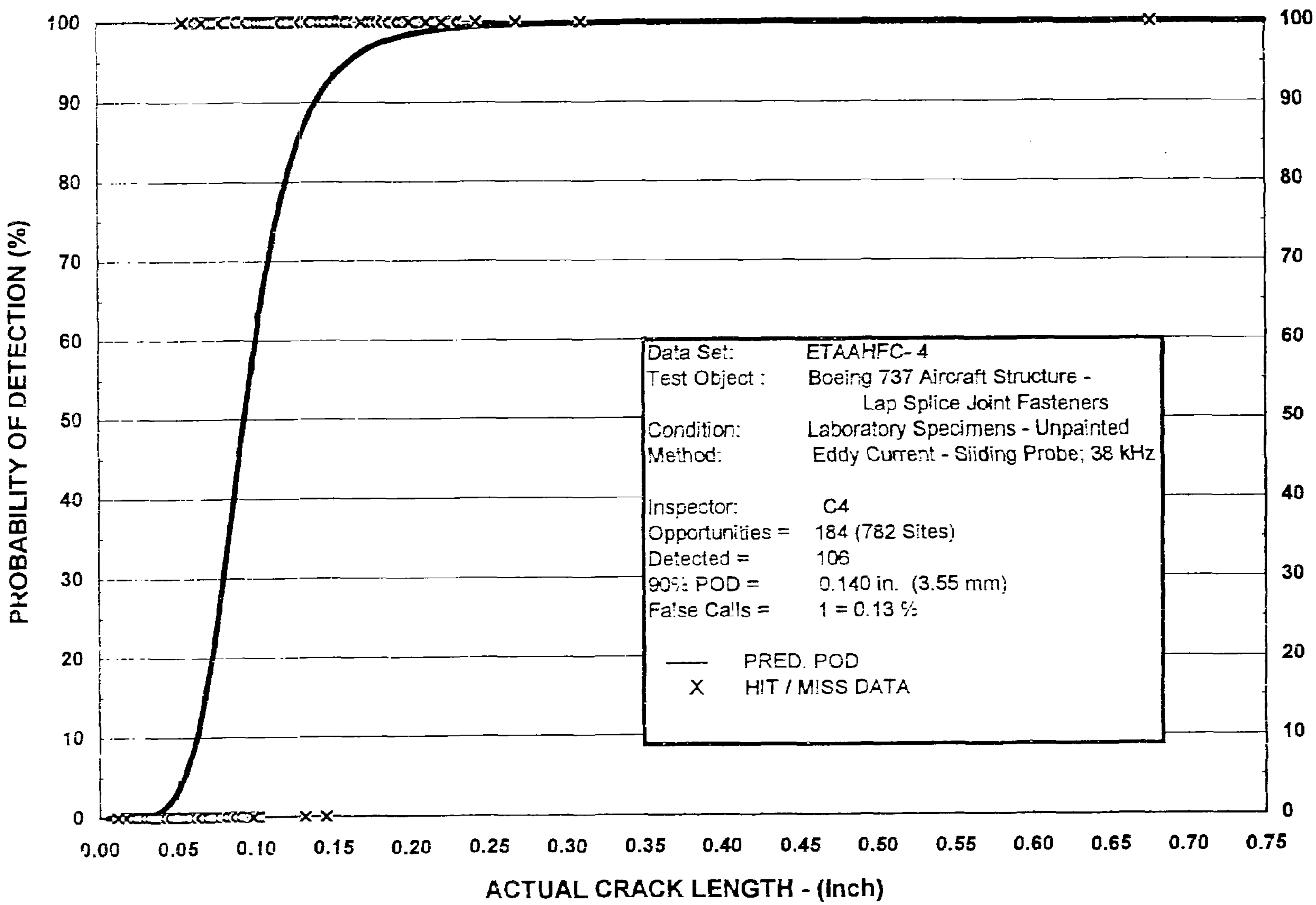


ET - 06 (5)C LAP SPLICE JOINT INSPECTION

06/95

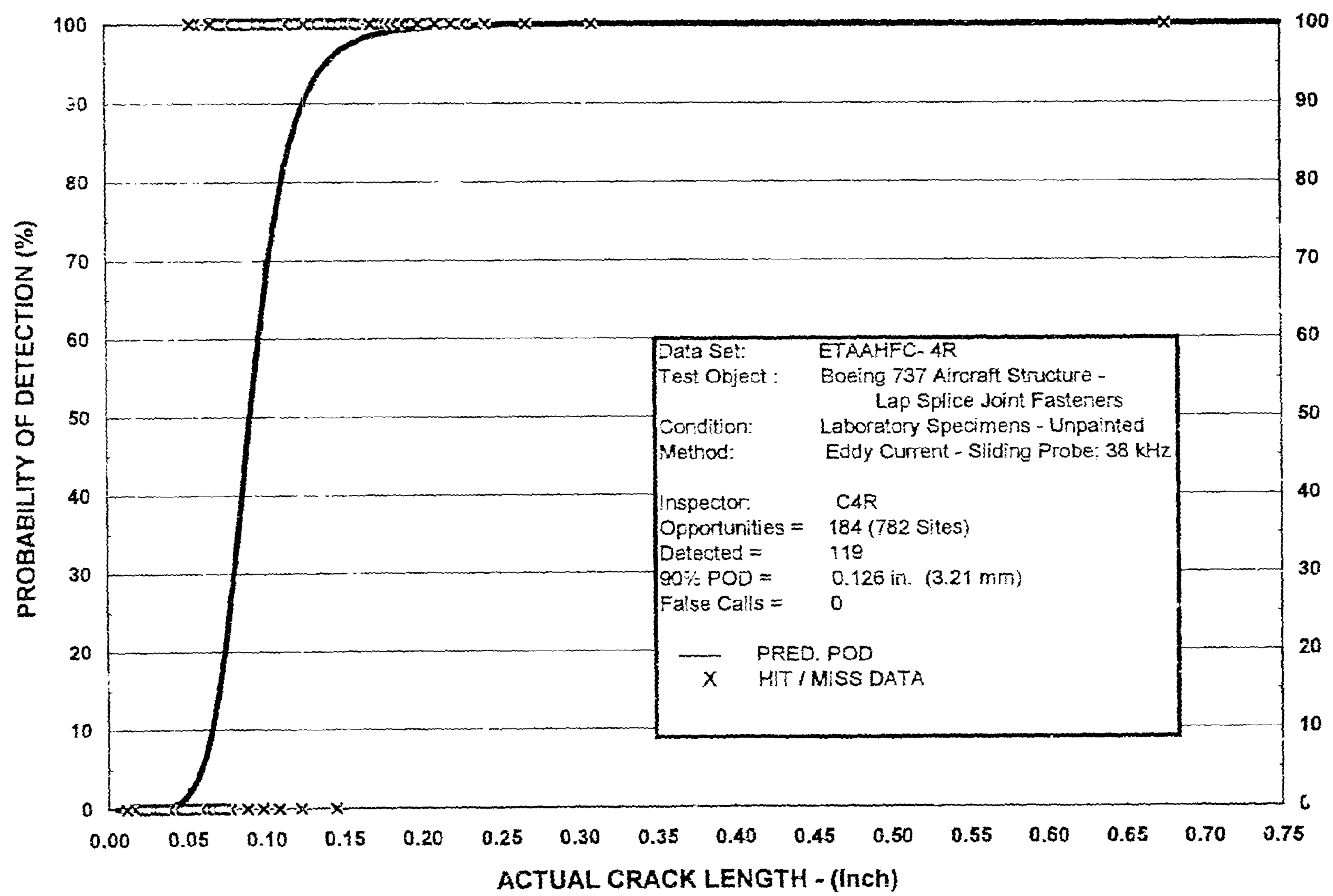
ETAAHFC-3

Facility C- Operator 3



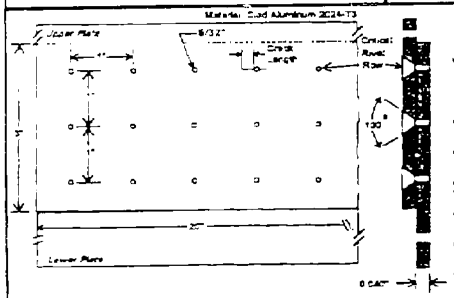
ETAAHFC-4
Facility C - Operator 4

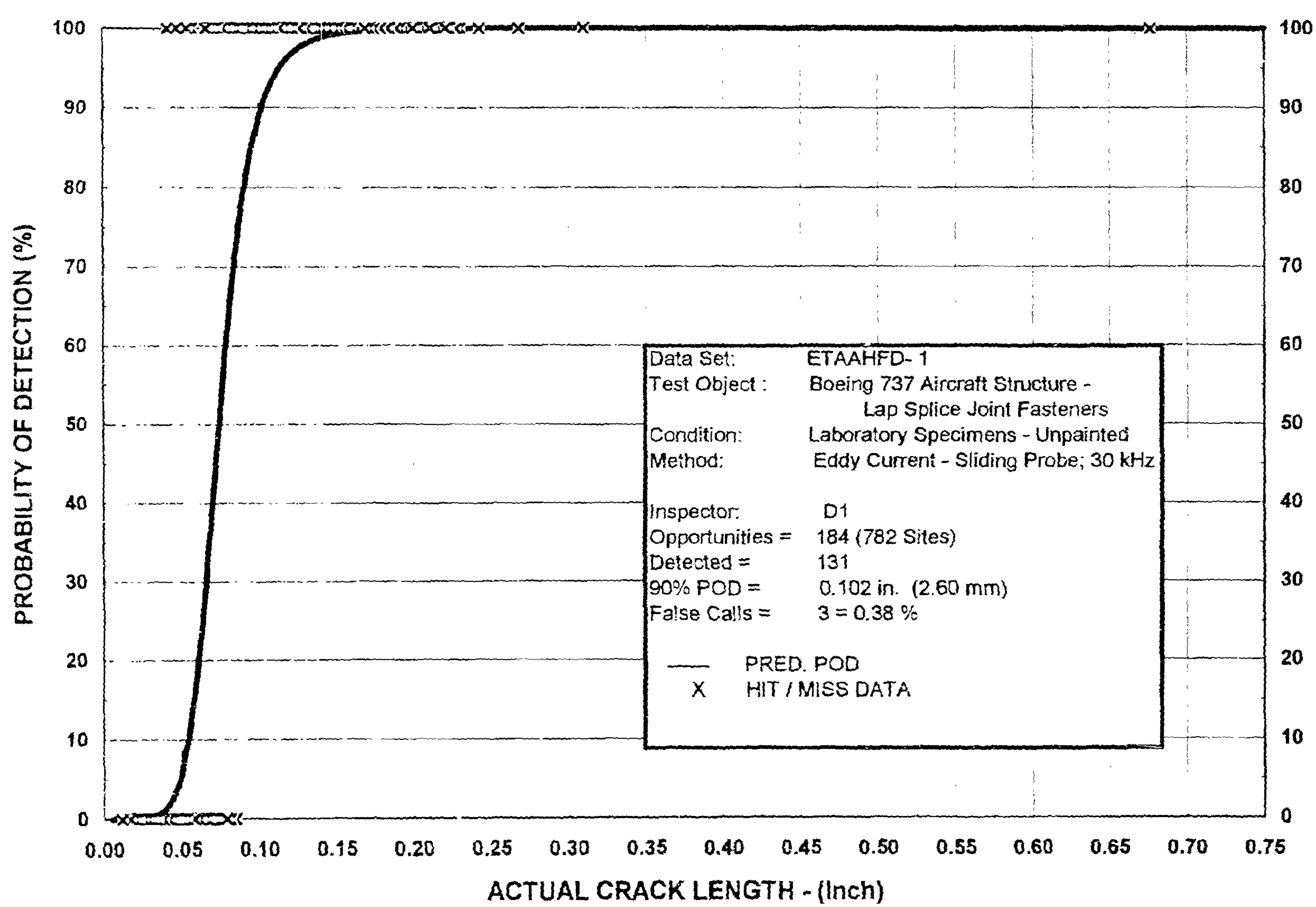
ET - 06 (5)C LAP SPLICE JOINT INSPECTION
06/95



ETAAHFC-4R
Facility C - Operator 4 / REPEAT

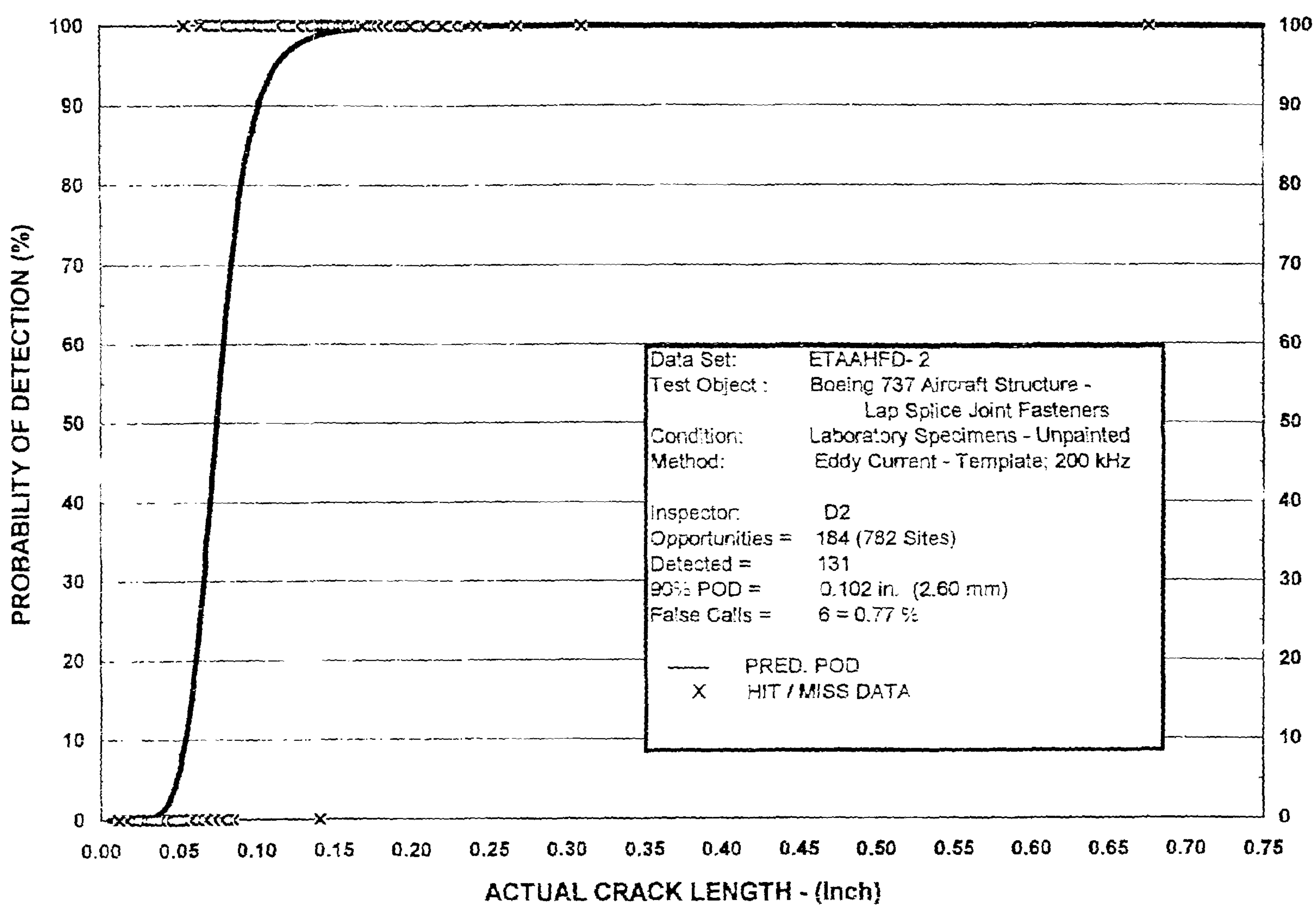
ET - 06 (5)C LAP SPLICE JOINT INSPECTION
06/95

ET-06 (5)D, CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current -template and sliding probe at 30 and 100 kHz. (NDT-19 and Hocking Locator UH)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**UNPAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a template and slidng probe-NOTE: Manual scan with a template is the "Calibration at 0.100" recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAFHD-1 ; D-2: D-2R, D-3 and D-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	D-1 = 131; D-2= 131; D-2R= 138, D-3= 145 and D-4= 147
FALSE CALLS:	D-1,3 = 0.38% ; D-2,6 = 0.77%; D-2R, 3 = 0.38%, D-3,29 = 3.71% and D-4,84 = 10.74%
REFERENCE:	DOT/FAA/CT-92/12.III Spencer, Floyd and Donald Schurman, **<u>Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment</u>**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.
	The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.
	The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]
	90% POD Length - "AS PRODUCED"
	D1= 0.102 in. (2.60 mm)
	D2= 0.102 in. (2.60 mm)
	D2R= 0.095 in. (2.40 mm)
	D3= 0.086 in. (2.19 mm)
	D4= 0.086 in. (2.19 mm)



ETAAHFD-1
Facility D - Operator 1

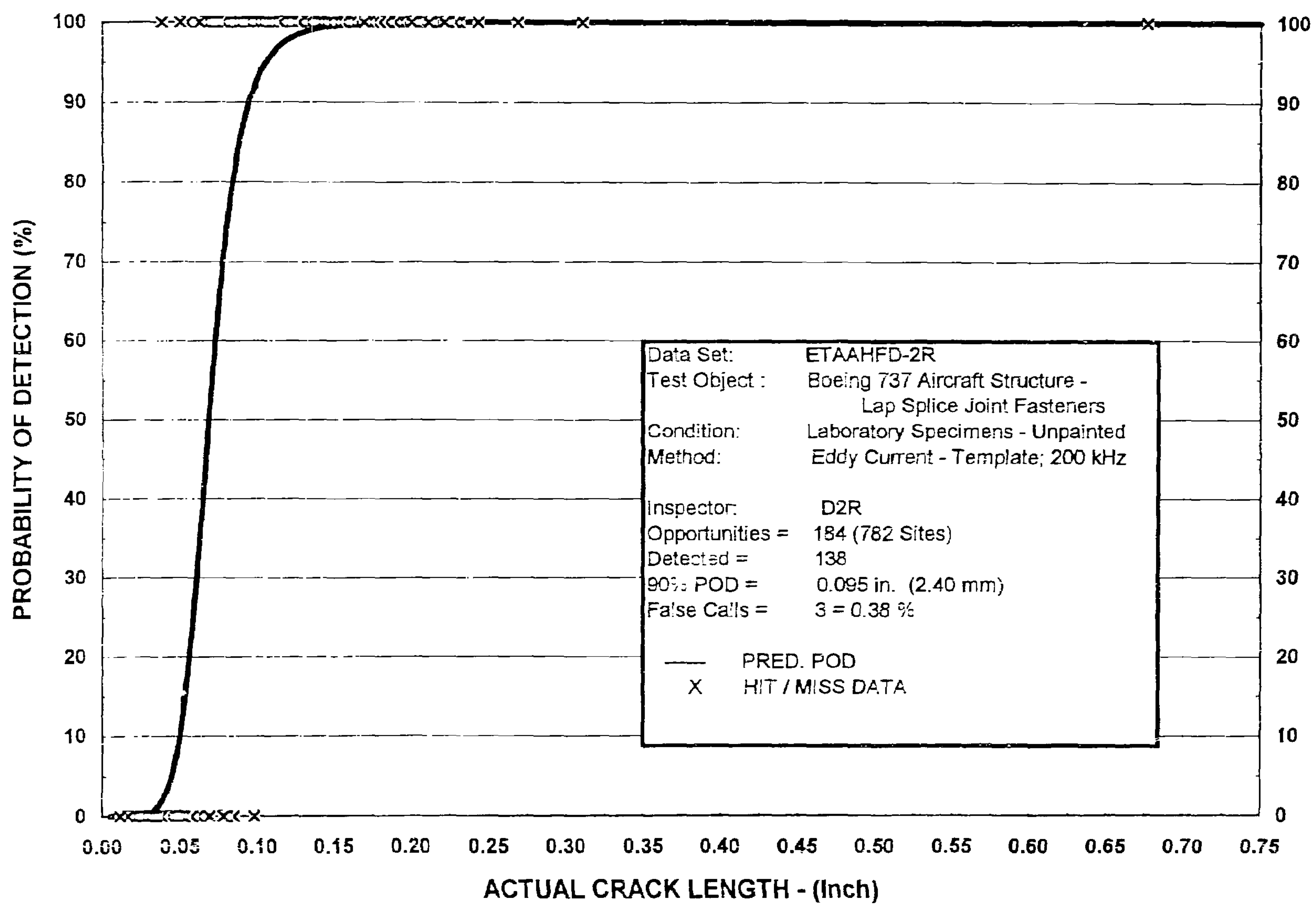
ET - 06 (5)D LAP SPLICE JOINT INSPECTION
6/95



ETAAHFD-2
Facility D - Operator 2

ET - 06 (5)D LAP SPLICE JOINT INSPECTION

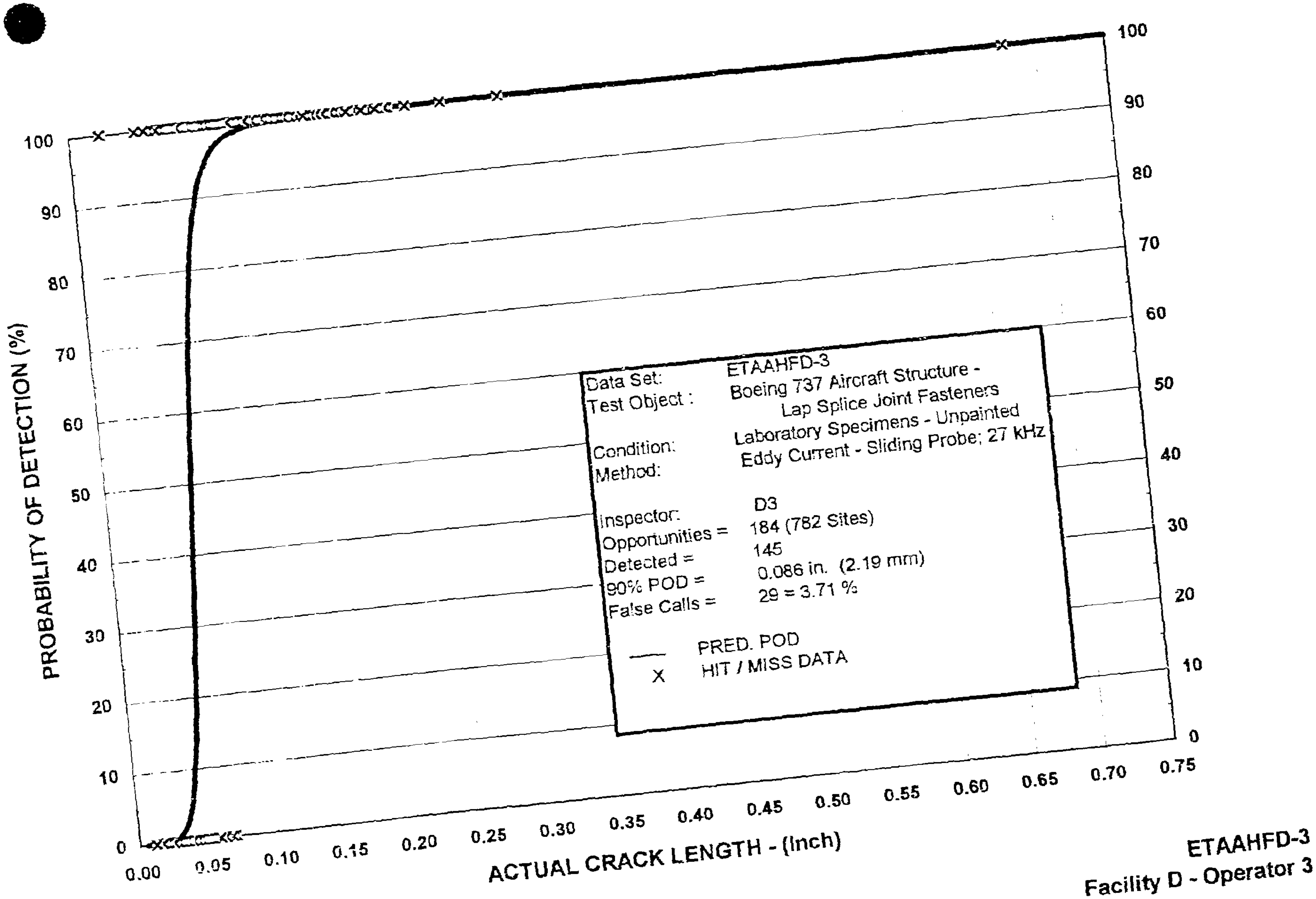
6/95



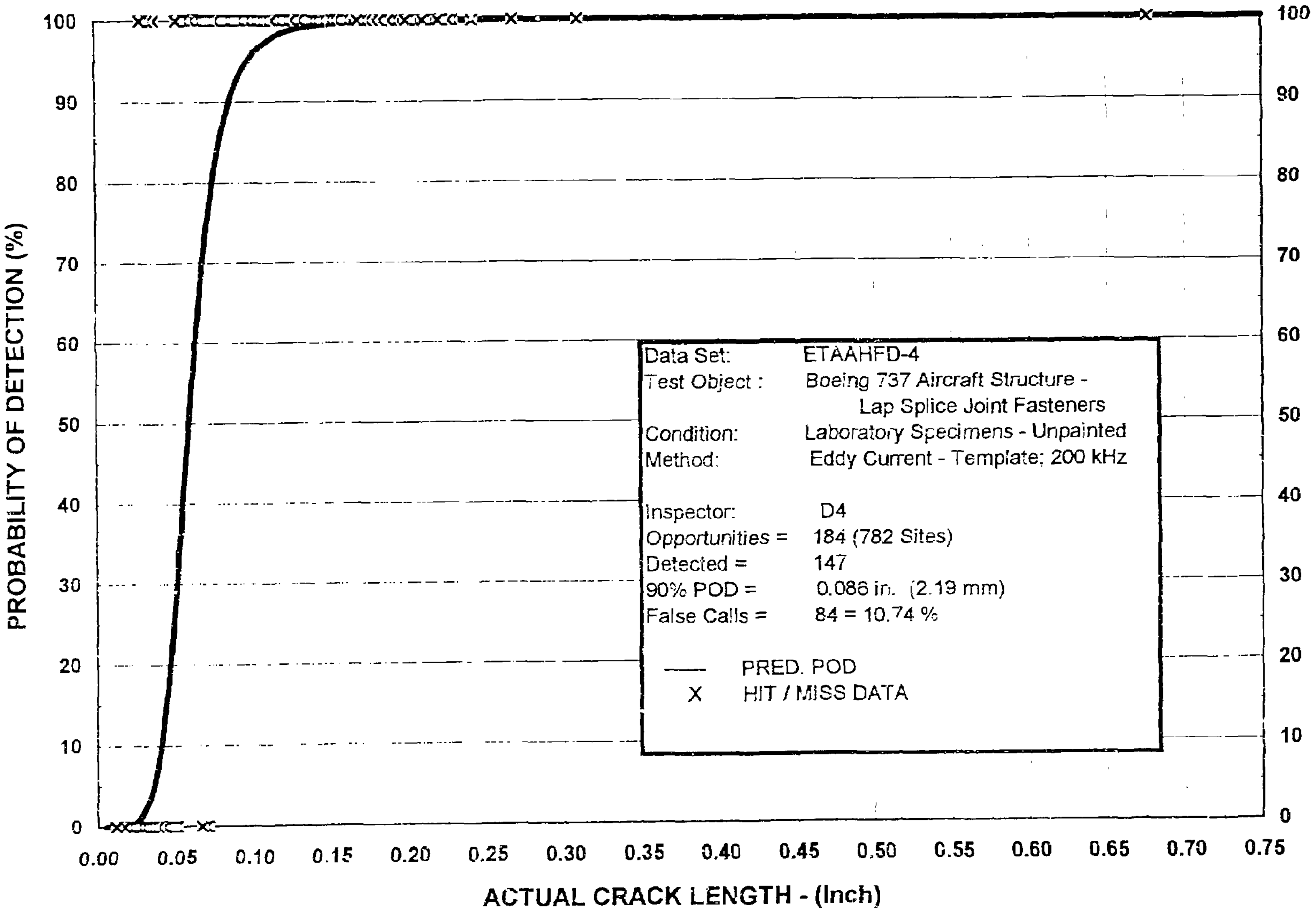
ETAAHFD-2R
Facility D - Operator 2 / REPEAT

ET - 06 (5)D LAP SPLICE JOINT INSPECTION

6/95



ET - 06 (5)D LAP SPLICE JOINT INSPECTION
6/95



ETAAHFD-4
Facility D - Operator 4

ET - 06 (5) LAP SPLICE JOINT INSPECTION

6/95

ET-06 (5)E, CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Contract Probe at 100 kHz nominal (75-150 kHz), Meter Readout (ED-520)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ----------------PAINTED
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a template ----------------NOTE: Manual scan with a template is the "Calibration at 0.100" recommended validation procedure.**
DATA SET IDENTIFIER:	ET-HFE-1 ; E-2; E-2R, E-3 and E-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	E-1 = 132 ; E-2= 126; E-2R= 125, E-3= 135 and E-4= 133
FALSE CALLS:	E-1,2 = 0.26% ; E-2,3 = 0.38%; E-2R,6 = 0.74%, E-3,2 = 0.26% and E-4,53 = 6.78%
REFERENCE:	DOT/FAA/CT-92/12,III Spencer, Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center estabiished at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
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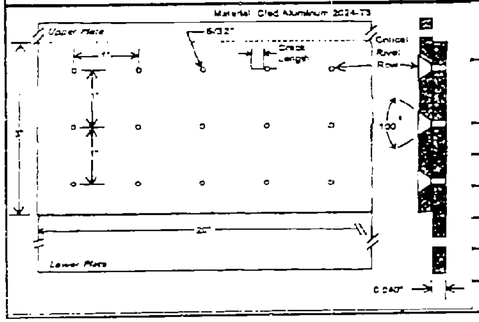
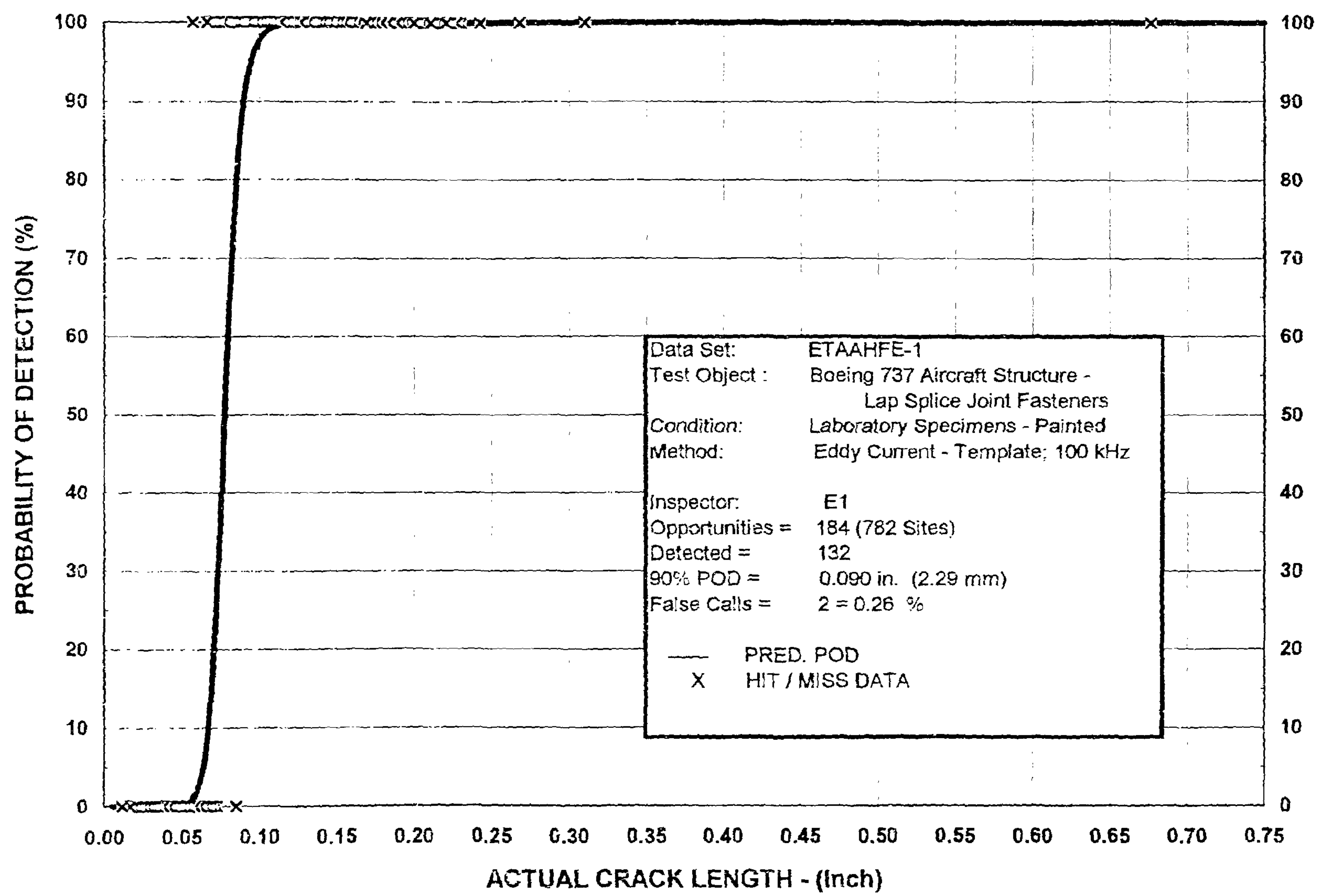
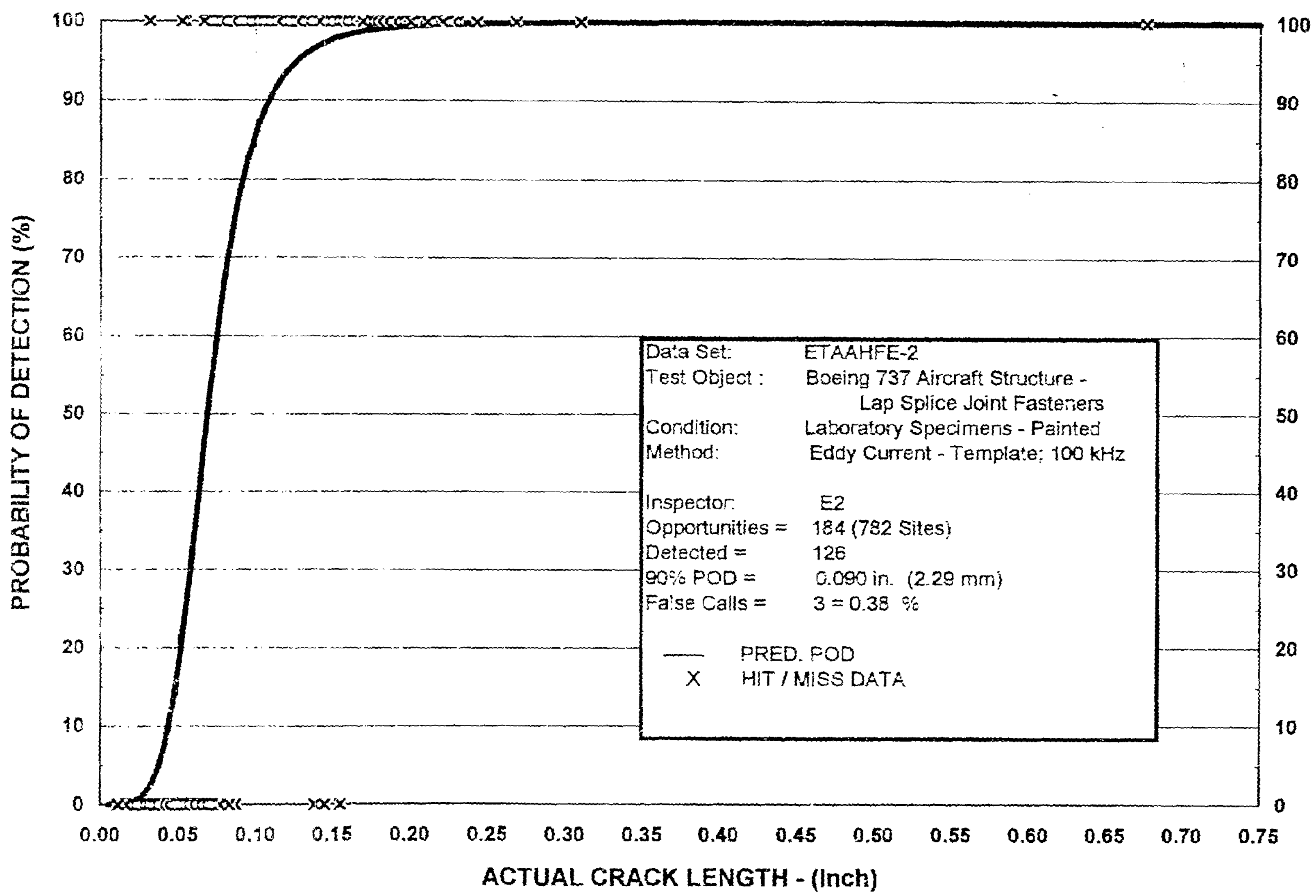
	The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.
	The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]
	90% POD Length - "AS PRODUCED"
	E1= 0.090 in. (2.29 mm)
	E2= 0.109 in. (2.76 mm)
	E2R= 0.110 in. (2.78 mm)
	E3= 0.101 in. (2.56 mm)
	E4= 0.107 in. (2.71 mm)



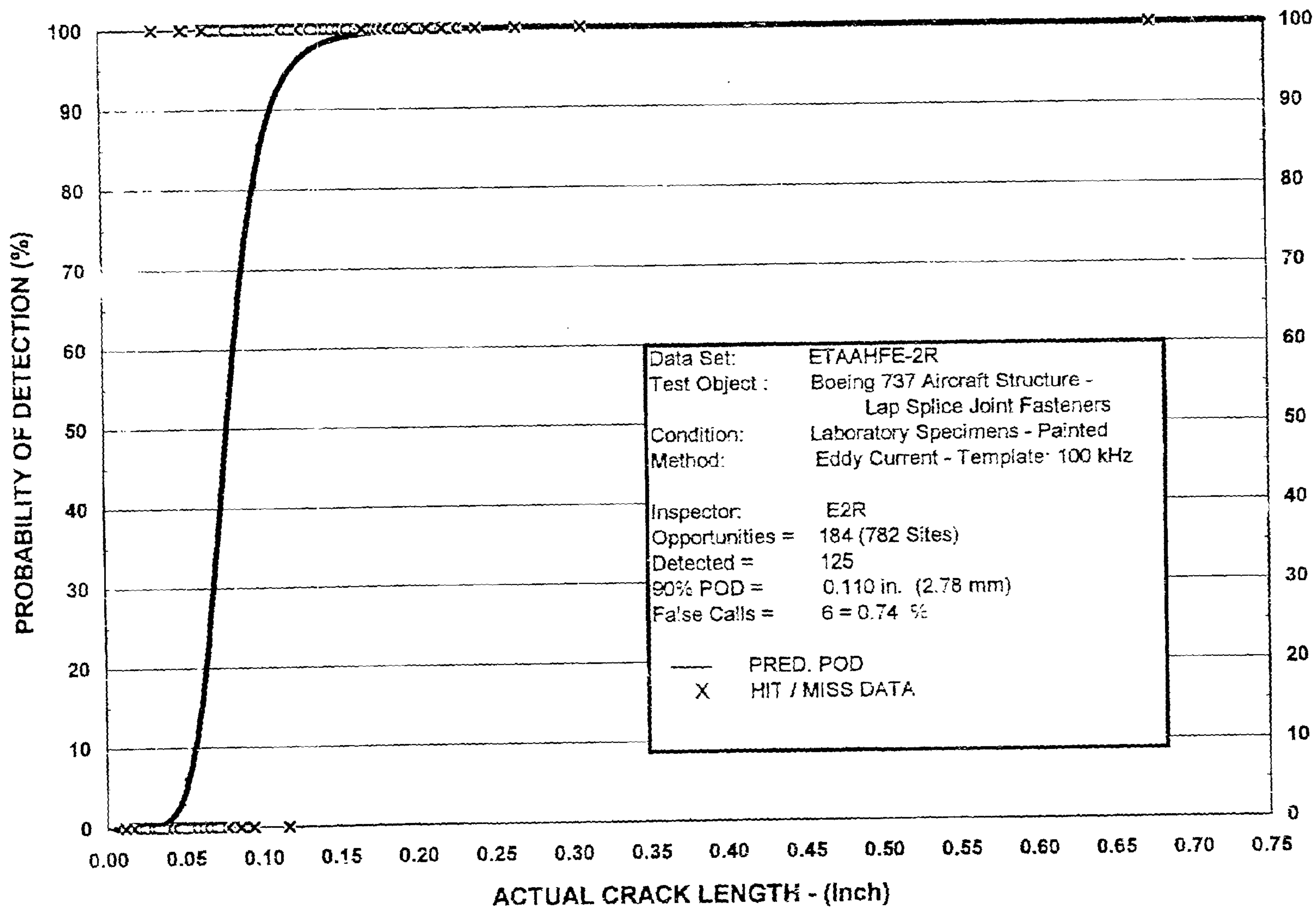
ETAAHFE-1
Facility E - Operator 1

ET - 06 (5)E LAP SPLICE JOINT INSPECTION
6/95



ETAAHFE-2
Facility E - Operator 2

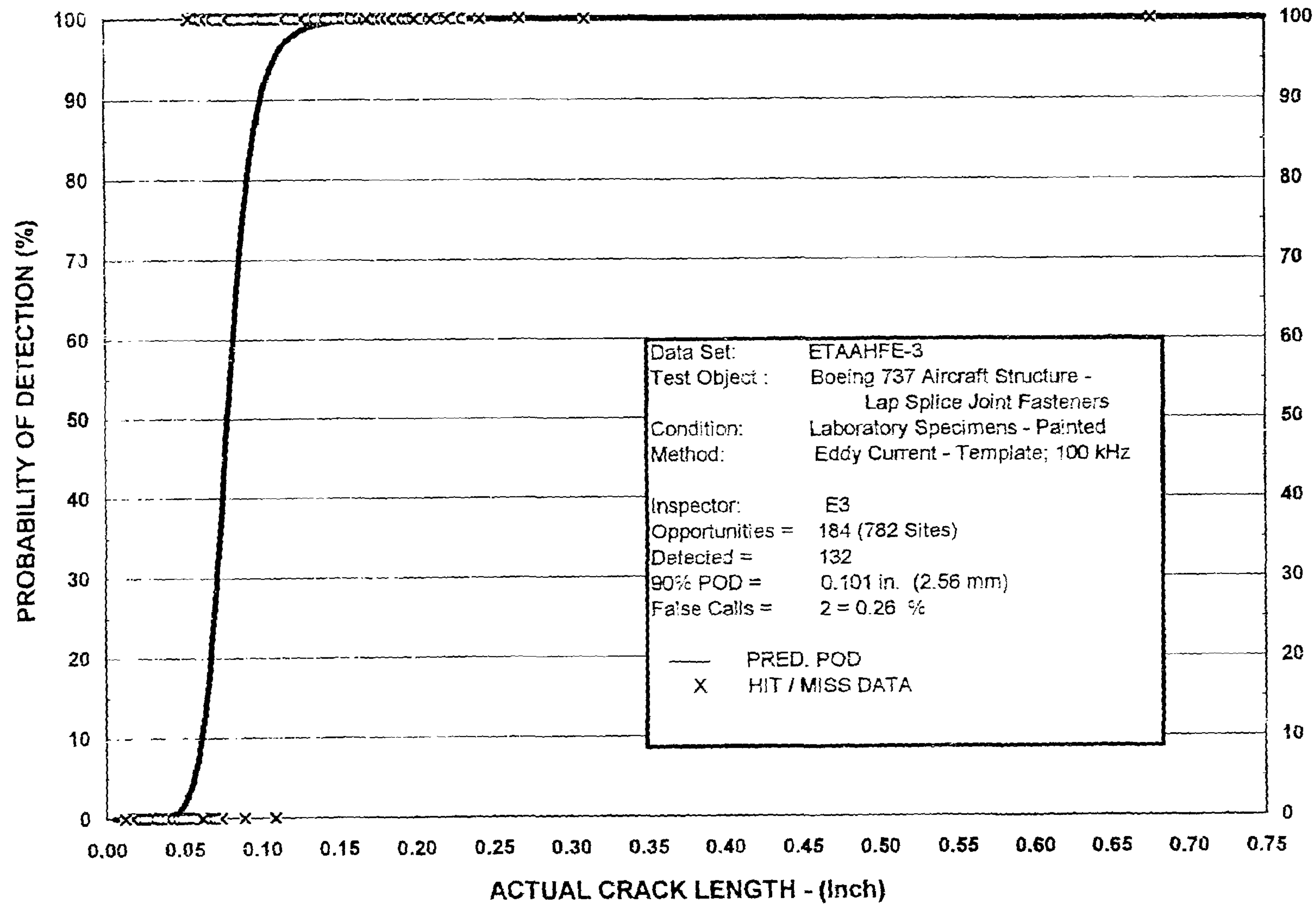
ET - 06 (5)E LAP SPLICE JOINT INSPECTION
6/95



ETAAHFE-2R
Facility E - Operator 2 / REPEAT

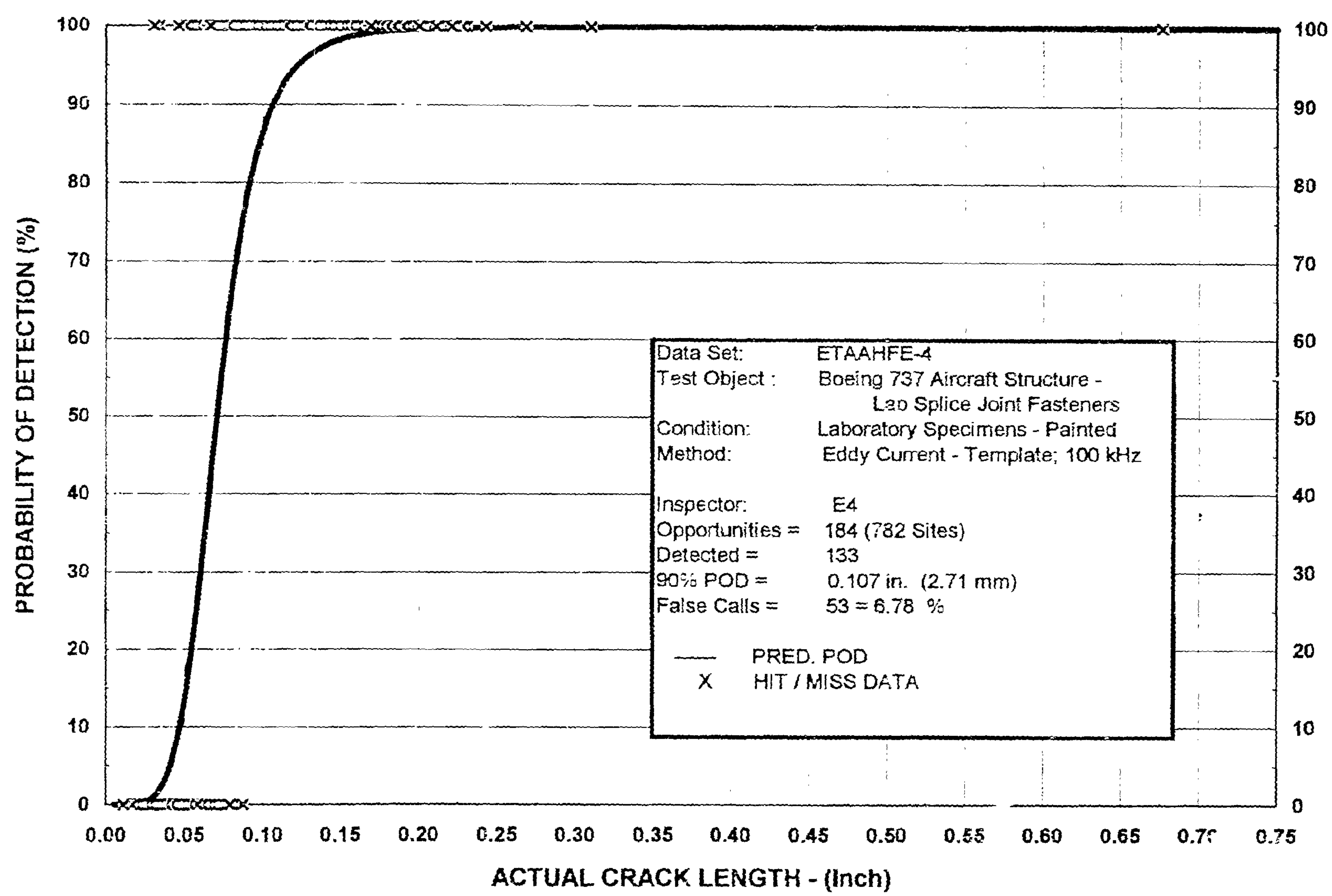
ET - 06 (5)E LAP SPLICE JOINT INSPECTION

6/95



ETAAHFE-3
Facility E - Operator 3

ET - 06 (5)E LAP SPLICE JOINT INSPECTION



ETAAHFE-4
Facility E - Operator 4

ET - 06 (5)E LAP SPLICE JOINT INSPECTION

6/95

ET-06 (5)F, CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Sliding Probe at 26 kHz (MIZ-20)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**UNPAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	***Manual scan with a sliding probe*——————NOTE: Manual scan with a template is the recommended validation procedure.** **"Calibration at 0.100"**
DATA SET IDENTIFIER:	ETAAHFF-1 ; F-2; F-3; F-4 and F-4R
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	F-1= 150 ; F-2= 103; F-3= 151; F-4= 152 and F-4R= 151
FALSE CALLS:	F-1,9 = 1.15% ; F-2,2 = 0.26%; F-3,0; F-4,3 = 0.38% and F-4R,13 = 1.66%
REFERENCE:	DOT/FAA/CT-92/12.III Spencer, Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
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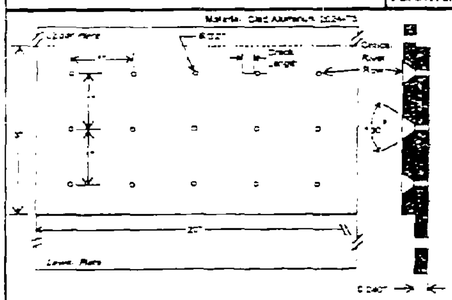
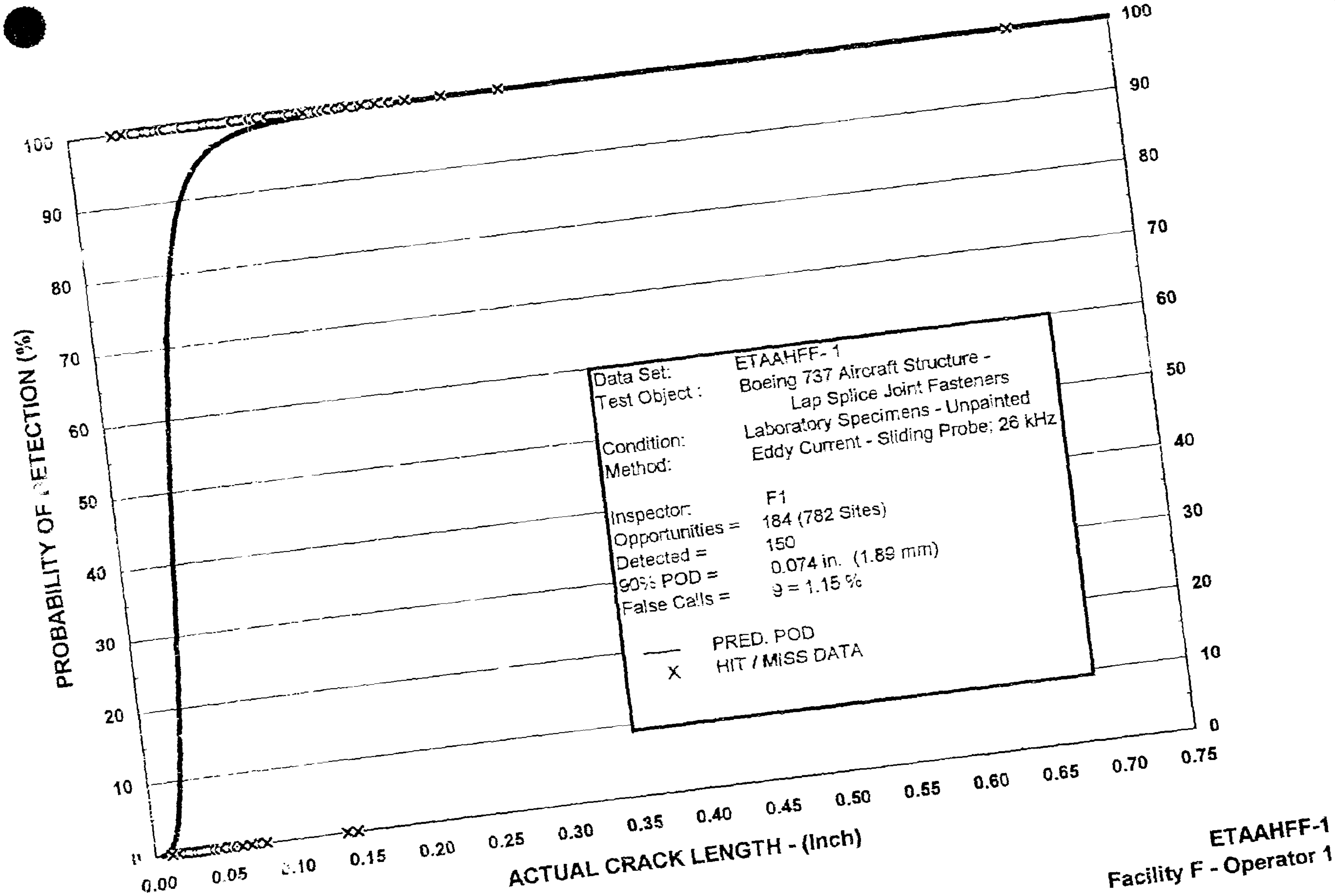


The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.

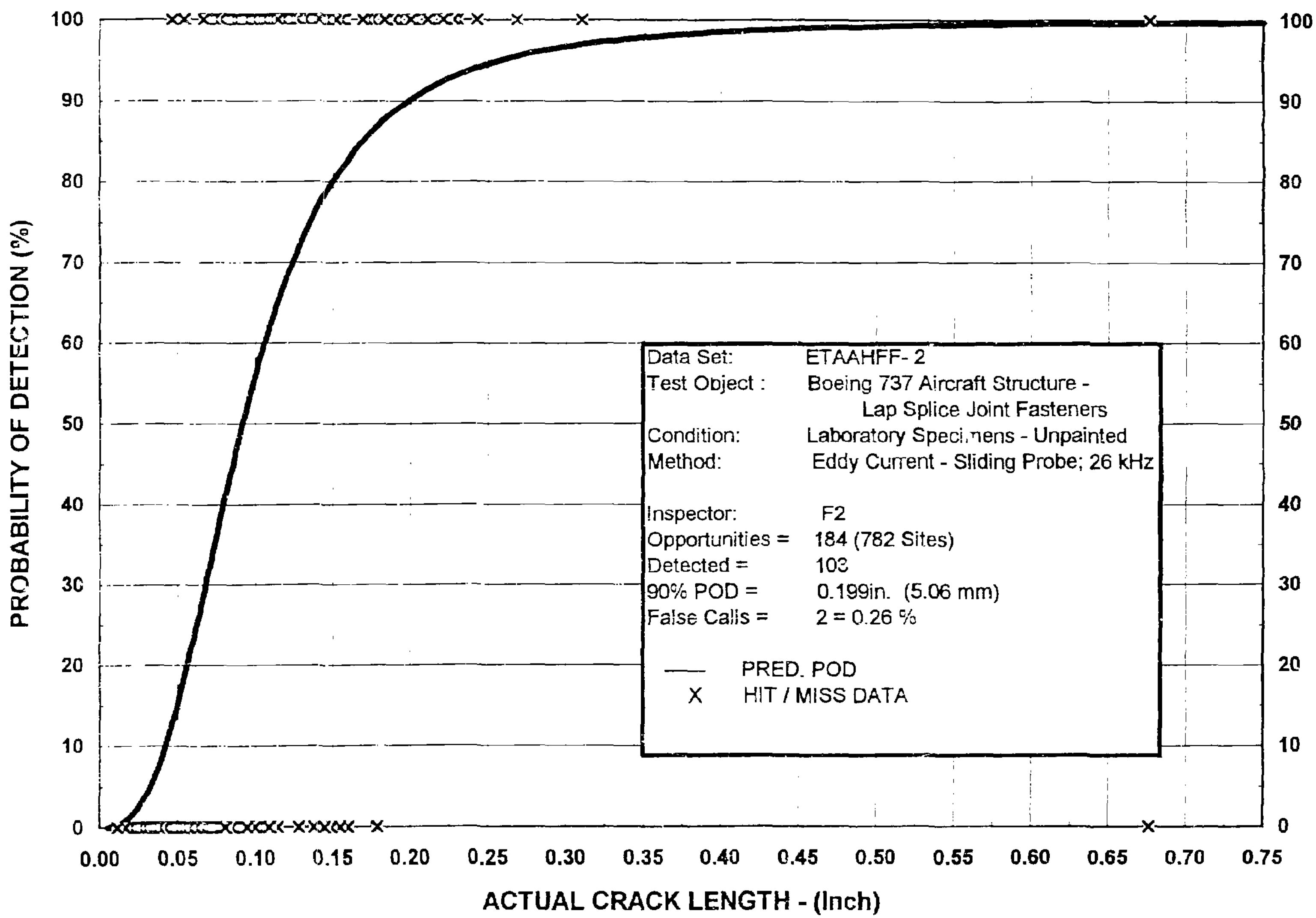
The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]

90% POD Length - "AS PRODUCED"
F1= 0.074 in. (1.89 mm)
F2= 0.199 in. (5.06 mm)
F3= 0.075 in. (1.91 mm)
F4= 0.061 in. (1.54 mm)
F4R= 0.066 in. (1.68 mm)



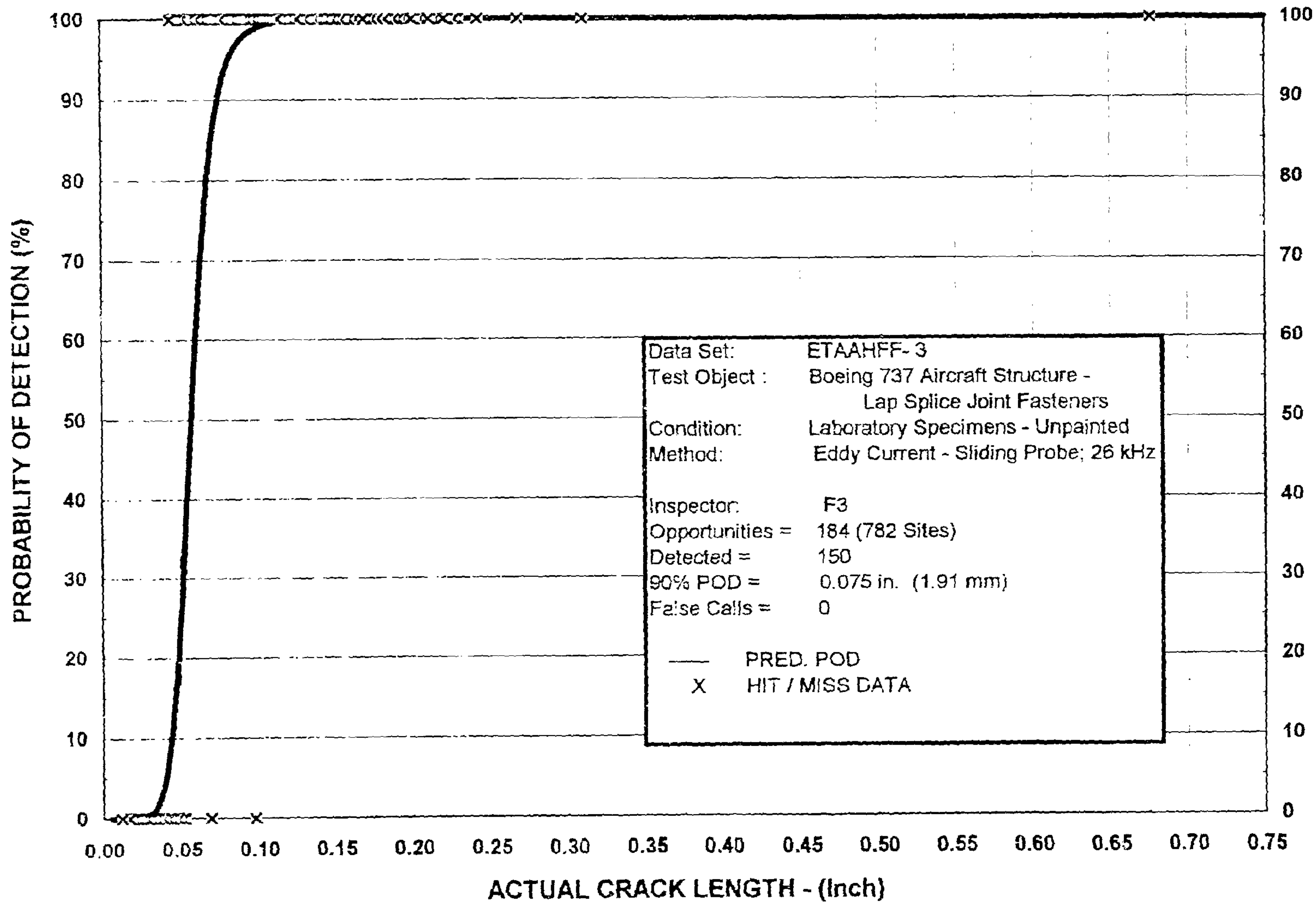
ETAAHFF-1
Facility F - Operator 1

ET - 0S (5)F LAP SPLICE JOINT INSPECTION
06/95



ETAAHFF-2
Facility F- Operator 2

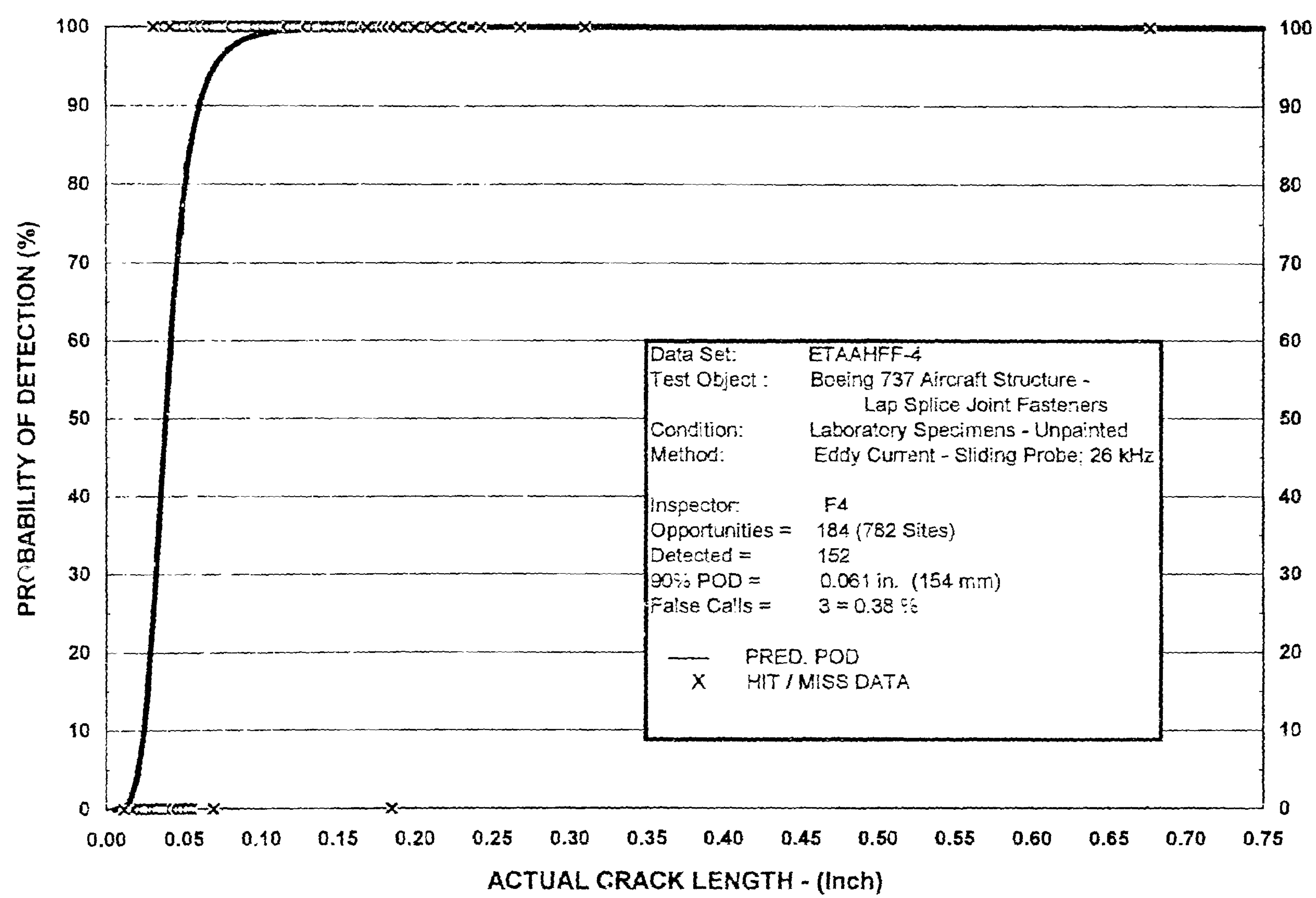
ET - 06 (5)F LAP SPLICE JOINT INSPECTION
06/95



ETAAHFF-3
Facility F - Operator 3

ET - 06 (5)F LAP SPLICE JOINT INSPECTION

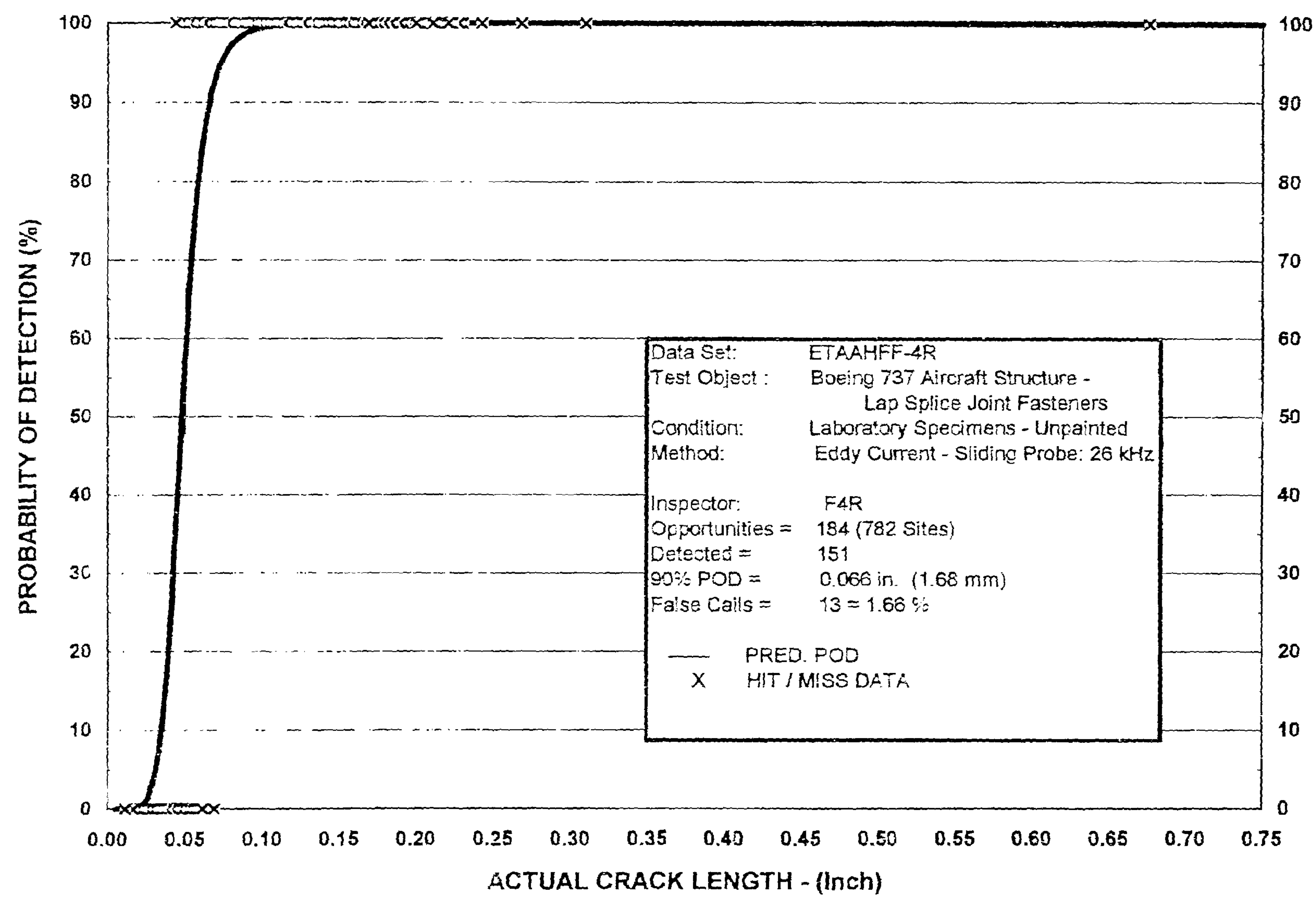
06/95



ETAAHFF-4
Facility F - Operator 4

ET - 06 (5)F LAP SPLICE JOINT INSPECTION

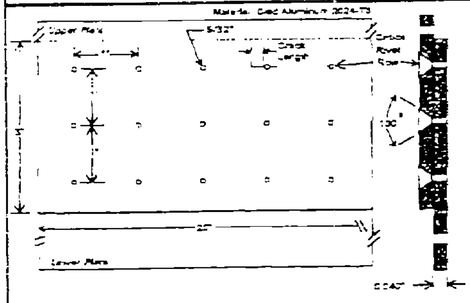
06/95



ETAAHFF-4R
Facility F - Operator 4 / REPEAT

ET - 06 (5)F LAP SPLICE JOINT INSPECTION
06/95

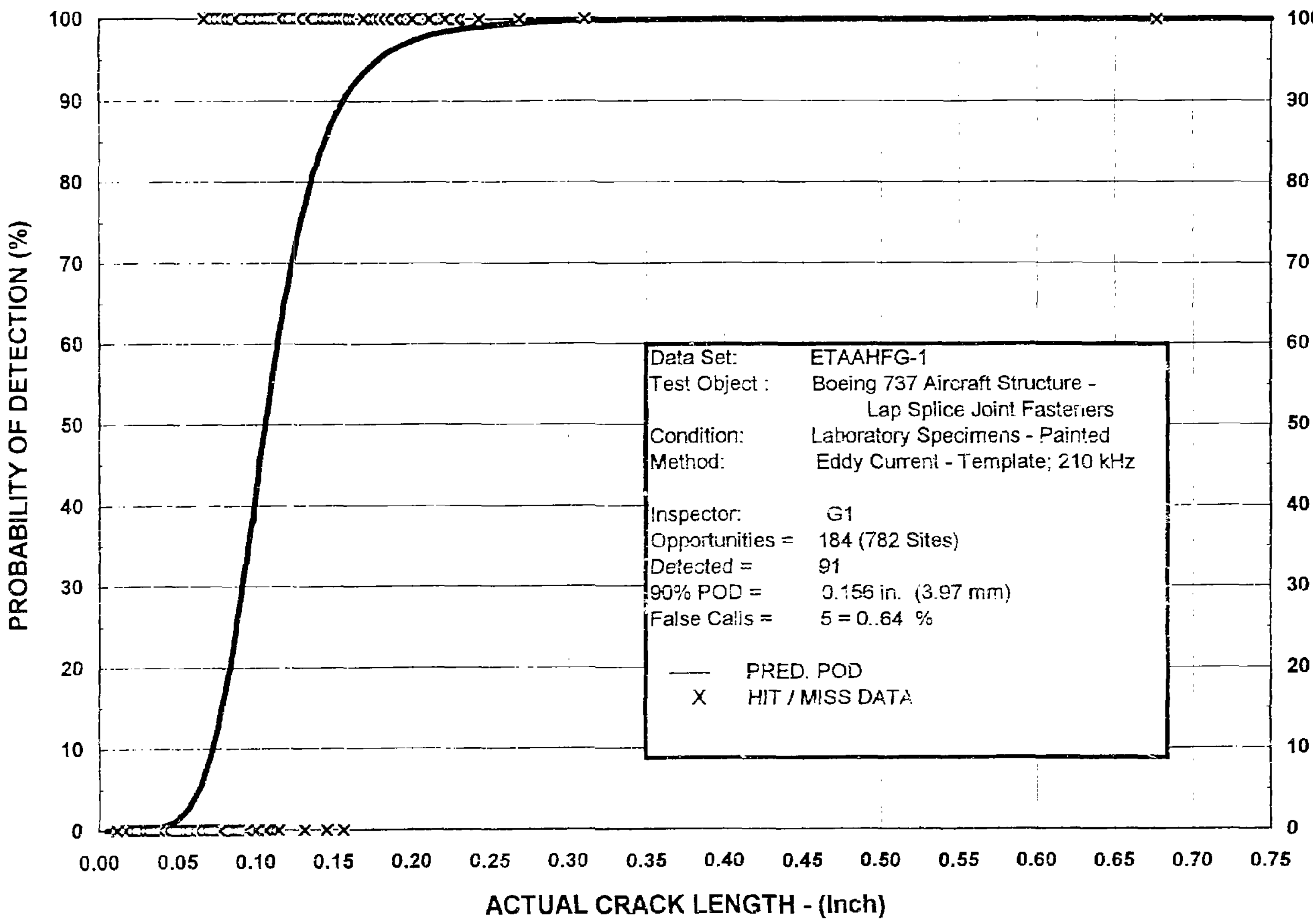
ET-06 (5)G CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Contract Probe at 210 kHz (MIZ -20)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-3
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**PAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a template ——————NOTE: Manual scan with a template is the "Calibration at 0.100" recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAFG-1; G-1R; G-2; G-3, and G-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	G-1= 91; G-1R= 94; G-2= 126; G-3= 79, and G-4= 124
FALSE CALLS:	G-1,5 = 0.64%; G-1R,4 = 0.51%; G-2,6 = 0.77%; G-3,10 = 1.26% and G-4,59 = 7.54%
REFERENCE:	DOT/FAA/CT-92/12.III Spencer, Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.



The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.

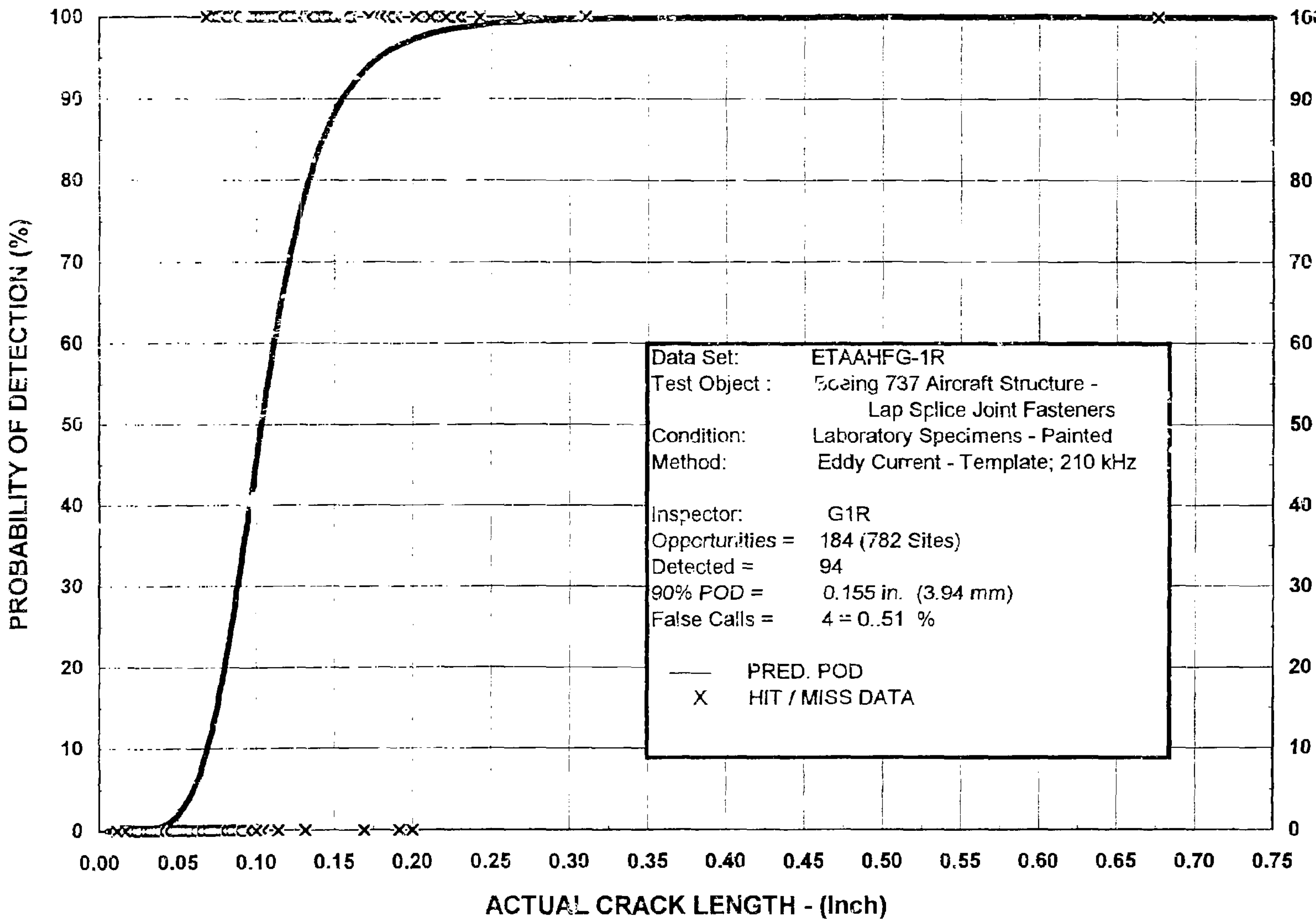
The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]

90% POD Length - "AS PRODUCED"
G1= 0.156 in. (3.97 mm)
G1R= 0.155 in. (3.94 mm)
G2= 0.094 in. (2.38 mm)
G3= 0.186 in. (4.74 mm)
G4= 0.146 in. (3.71 mm)



ETAAHFG-1
Facility G - Operator 1

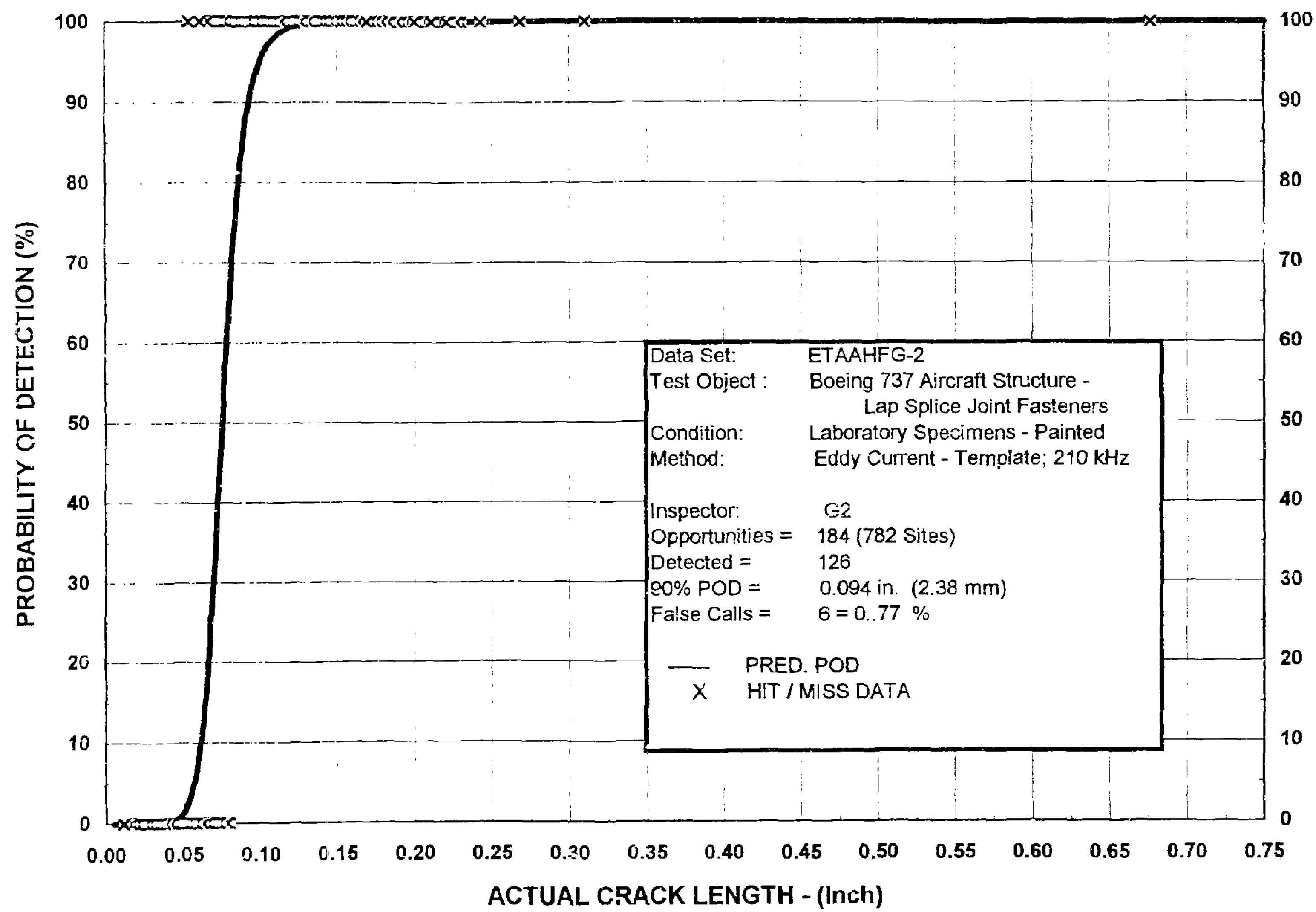
ET - 06 (5)G LAP SPLICE JOINT INSPECTION
06/95



ETAAHFG-1R
Facility G - Operator 1 / REPEAT

ET - 06 (5)G LAP SPLICE JOINT INSPECTION

06/95

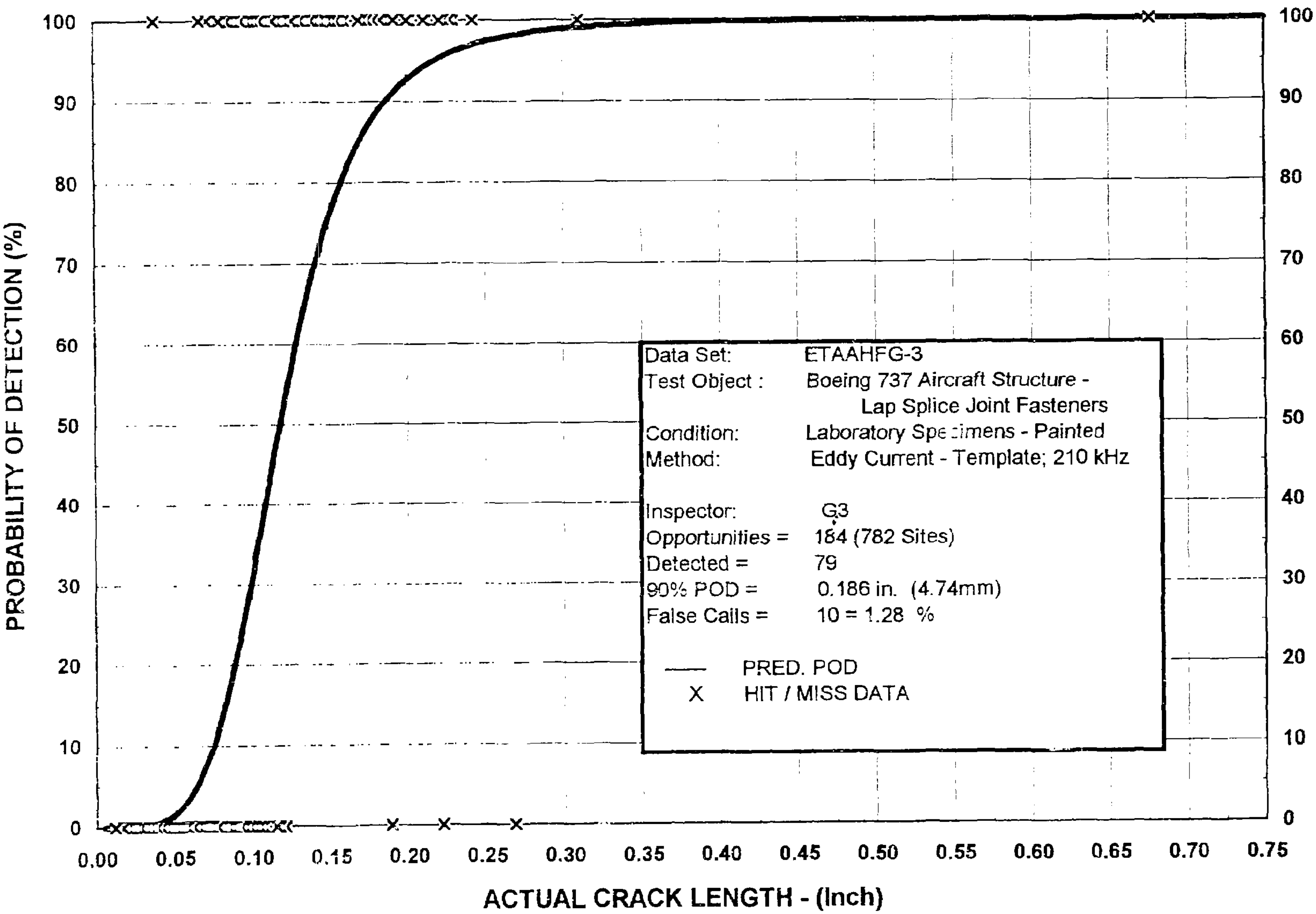


ET - 06 (5)G LAP SPLICE JOINT INSPECTION

06/95

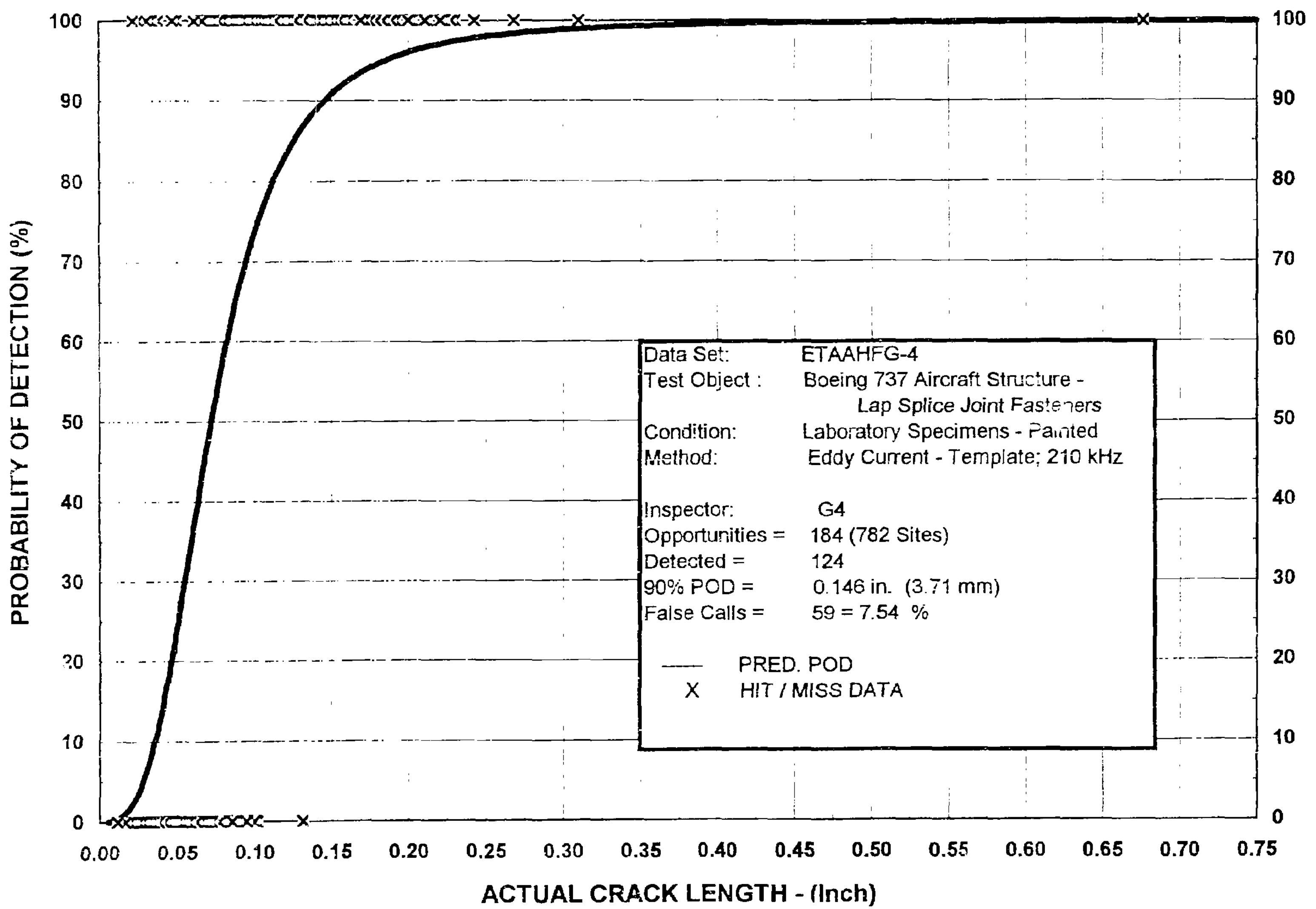
ETAAHFG-2

Facility G - Operator 2



ETAAHFG-3
Facility G - Operator 3

ET - 06 (5)G LAP SPLICE JOINT INSPECTION
06/95

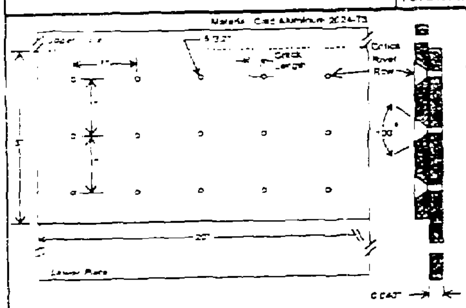


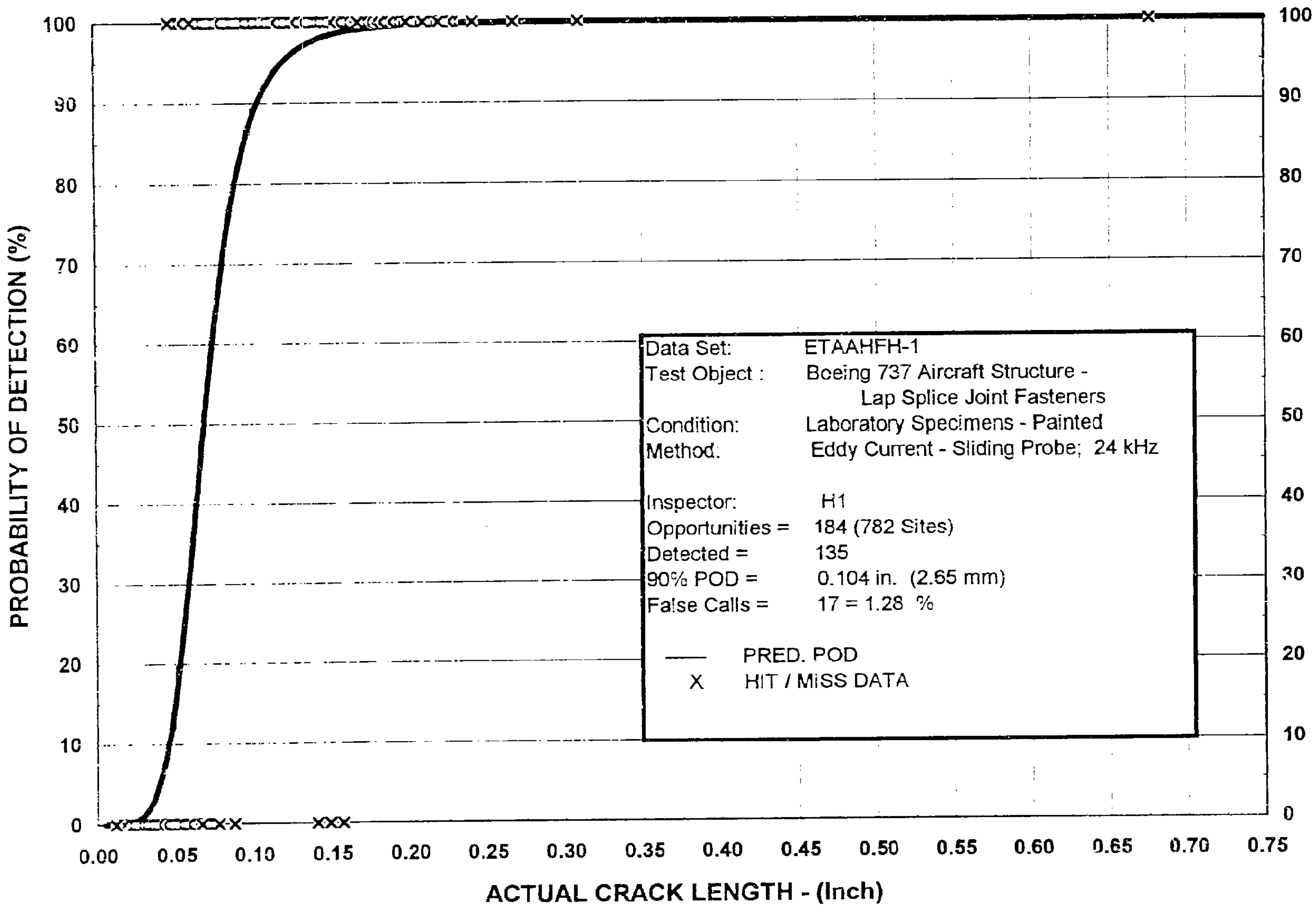
ETAAHFG-4

Facility G - Operator 4

ET - 06 (5)G LAP SPLICE JOINT INSPECTION

06/95

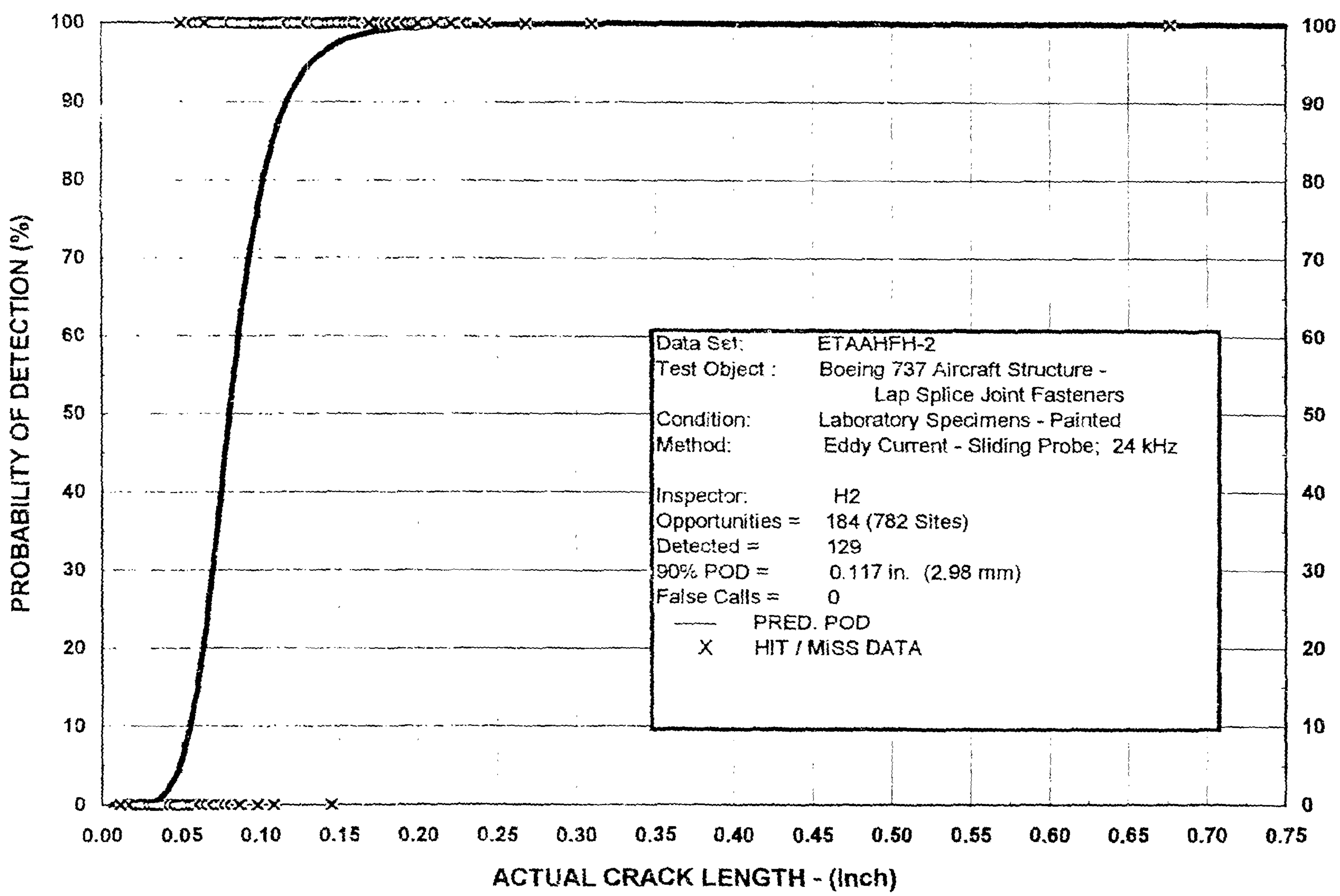
ET-06 (5)H, CRACK LENGTH	**DATA SET DESCRIPTION**
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75" radius)
NDE PROCEDURE:	Eddy Current - Sliding Probe at 24 kHz (MIZ -20)
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**PAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a slidng probe——————NOTE: Manual scan with a template is the recommended validation procedure.** **"Calibration at 0.100"**
DATA SET IDENTIFIER:	ETAAFH-1 ; H-2; H-2R; H-3 and H-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks
DETECTED:	H-1 = 135 ; H-2 = 129; H-2R = 138; H-3 = 119 and H-4 = 126
FALSE CALLS:	H-1,17 = 1.28% ; H-2.0; H-2R,0; H-3,3 = 0.38% and H-4,24 = 3.07%
REFERENCE:	DOT/FAA/CT-92/12,III Spencer, Floyd and Donald Schurman, **<u>Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment</u>**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION:	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.
	The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.
	The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]
	90% POD Length - "AS PRODUCED"
	H1= 0.104 in. (2.65 mm)
	H2= 0.117 in. (2.98 mm)
	H2R= 0.103 in. (2.61 mm)
	H3= 0.135 in. (3.44 mm)
	H4= 0.134 in. (3.39 mm)



ETAAHFH-1
Facility H - Operator 1

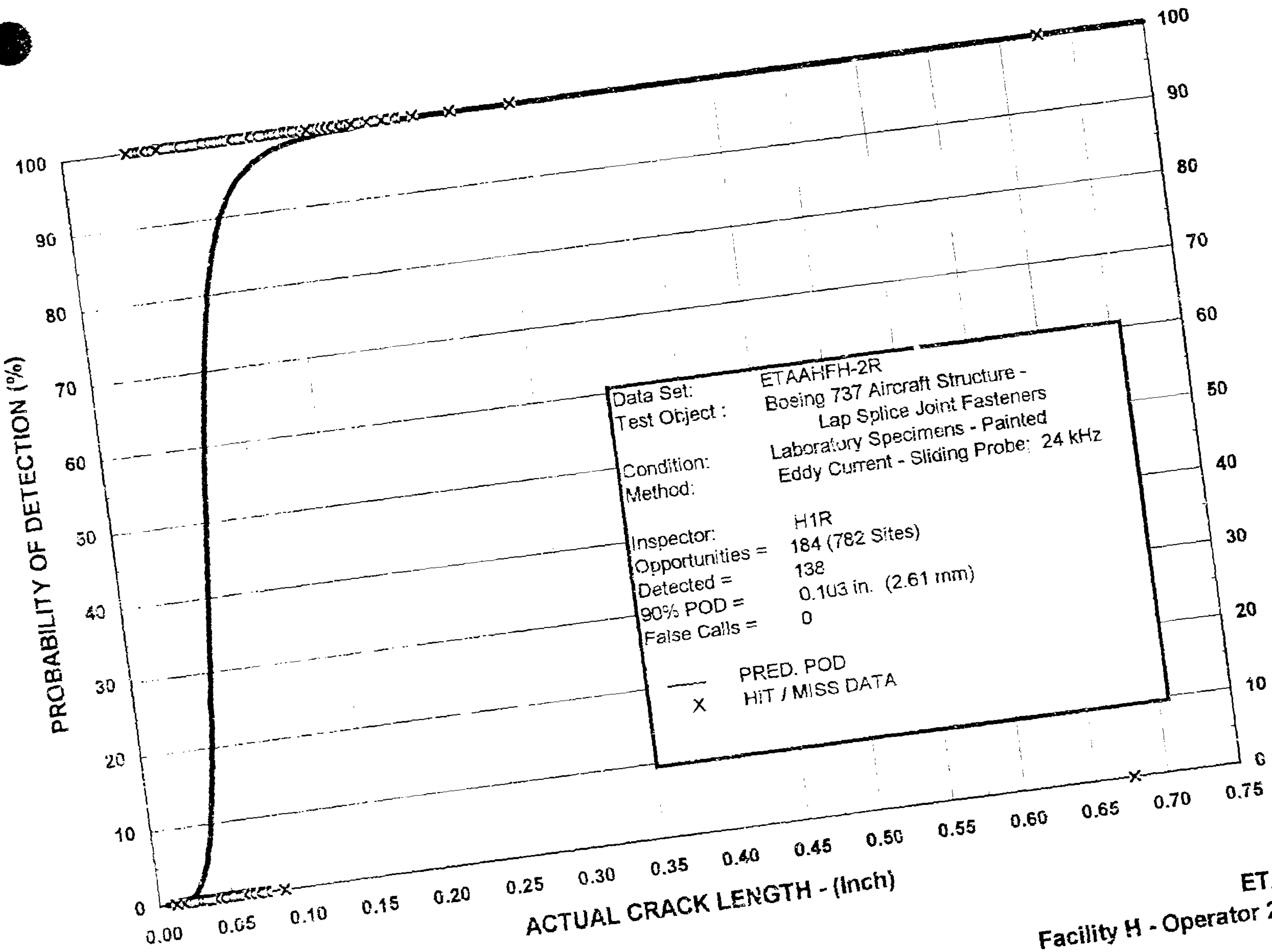
ET - 06 (5)H LAP SPLICE JOINT INSPECTION

06/95



ETAAHF01H-2
Facility H - Operator 2

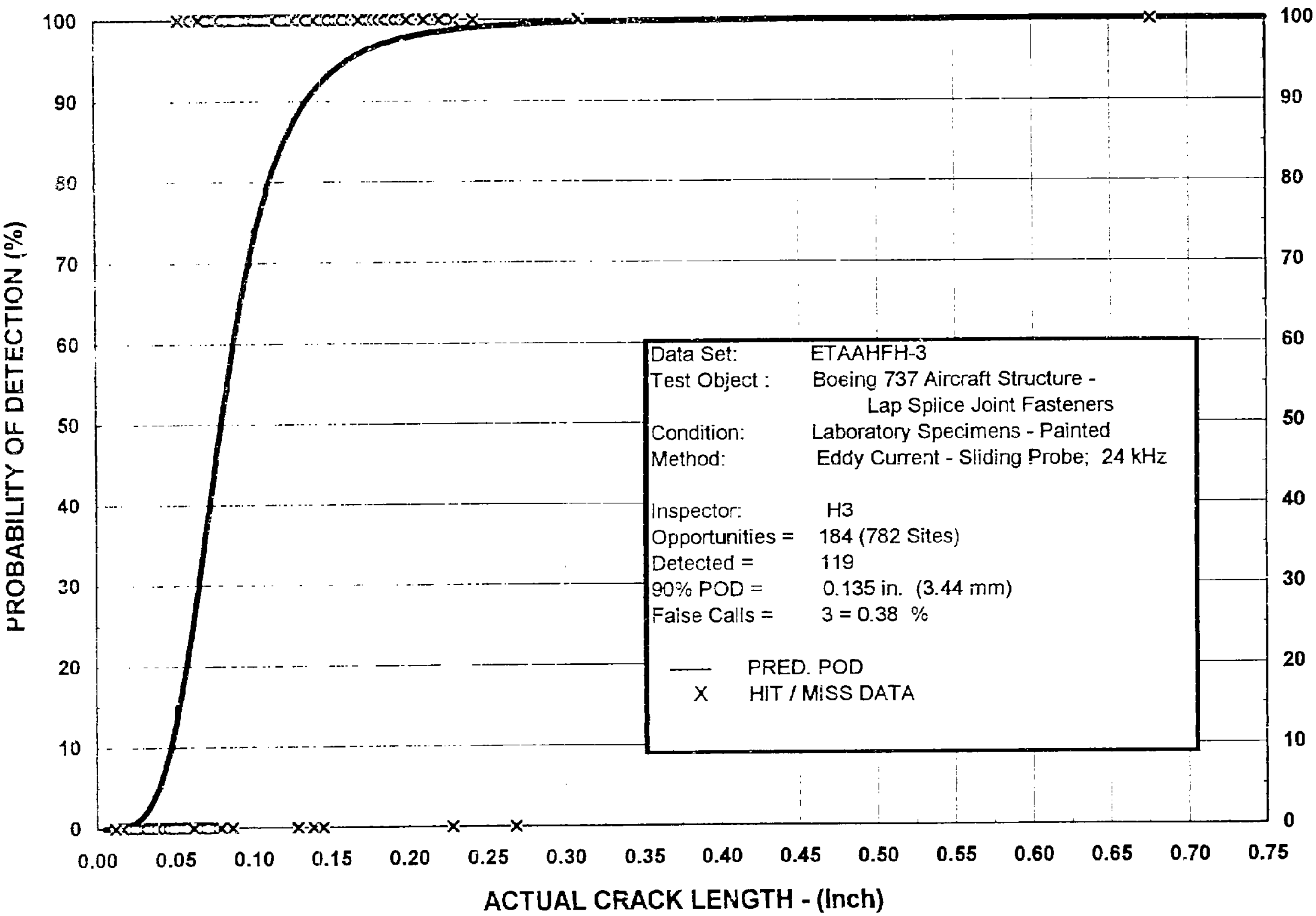
ET - 06 (5)H LAP SPLICE JOINT INSPECTION
06/95



ETAAHFH-2R
Facility H - Operator 2 / REPEAT

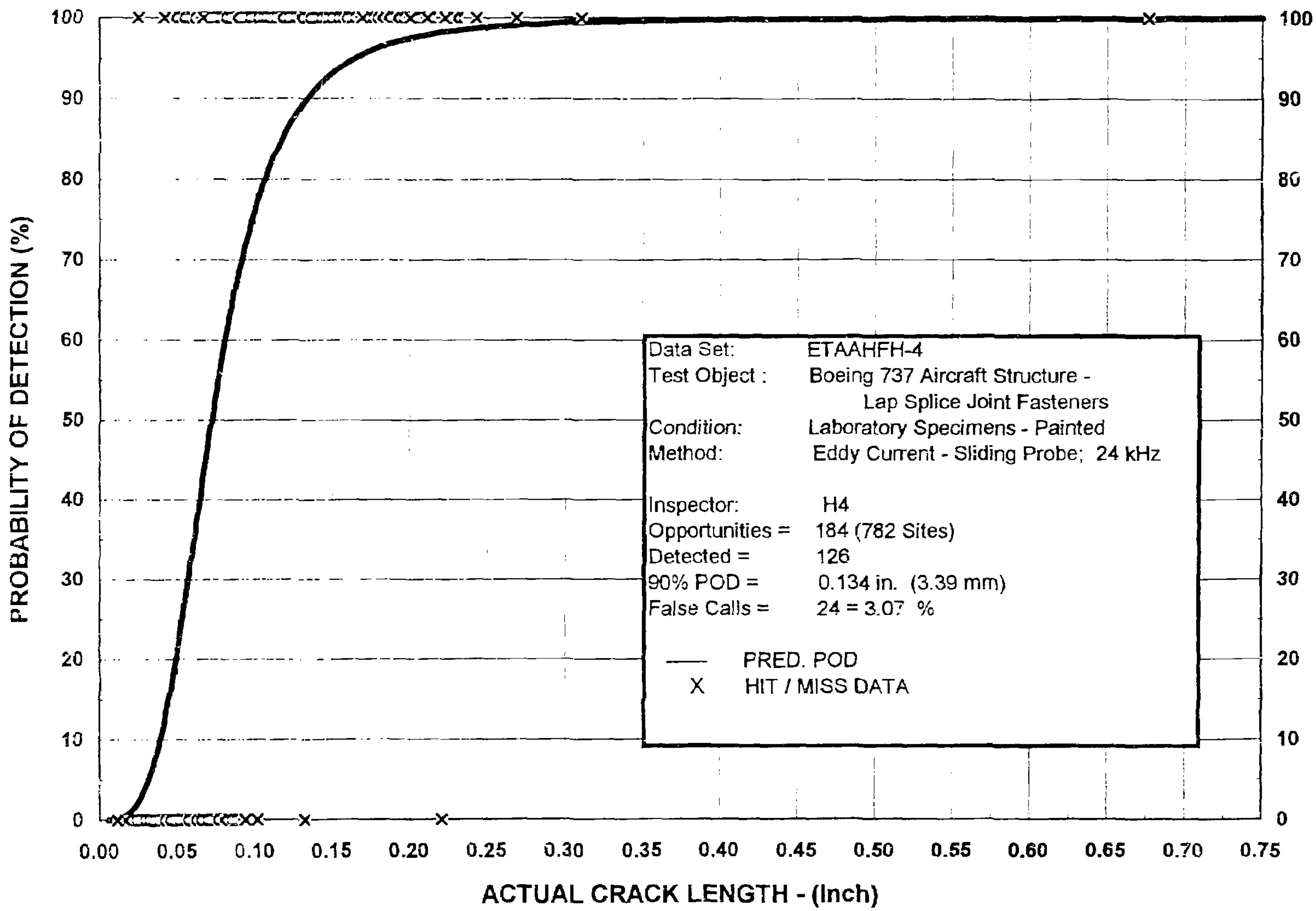
ET - 06 (5)H LAP SPLICE JOINT INSPECTION

06/95



ETAAHFH-3
Facility H - Operator 3

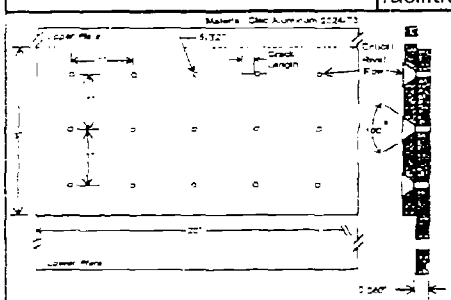
ET - 06 (5)H LAP SPLICE JOINT INSPECTION
06/95



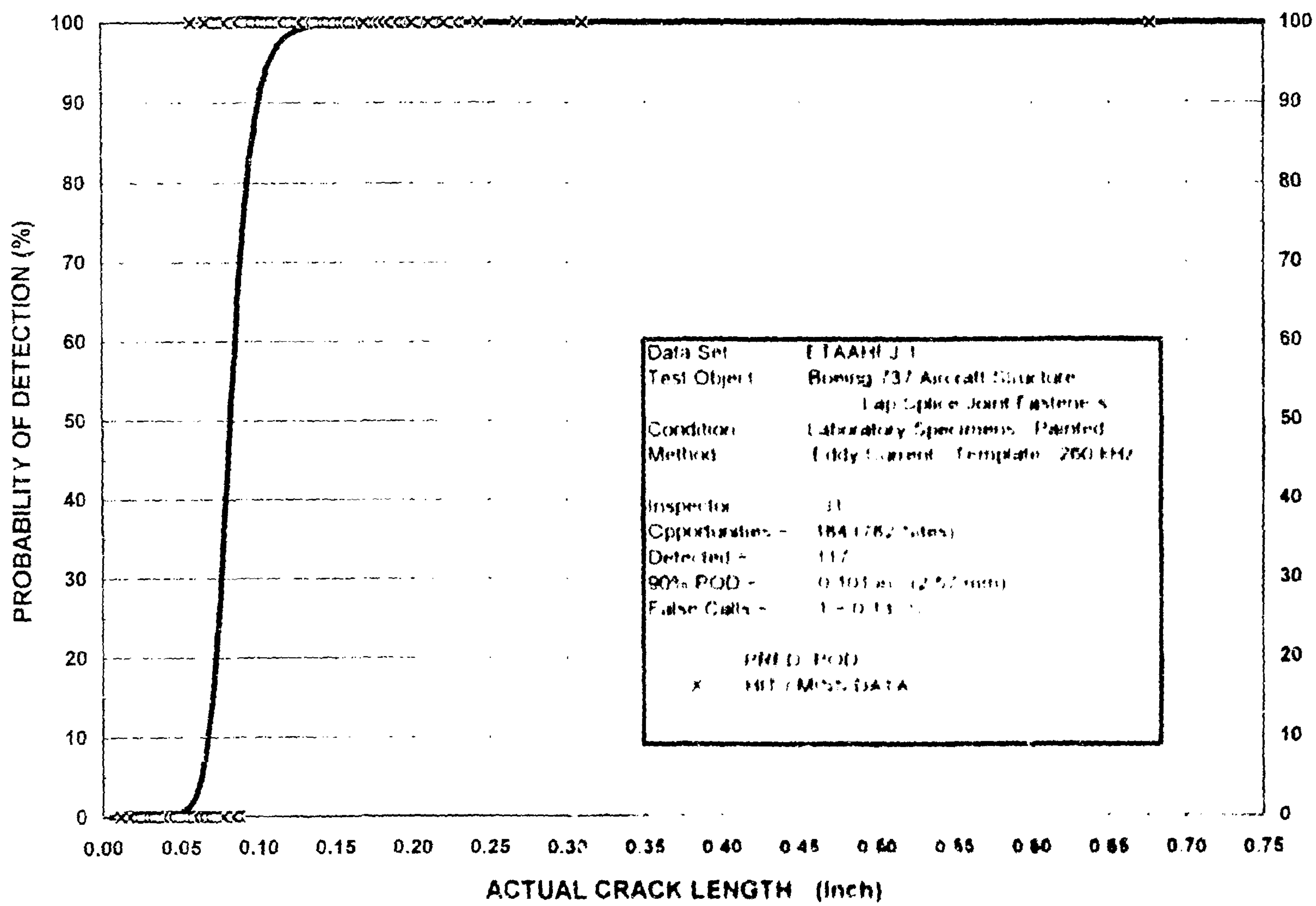
ETAAHF01H-4
Facility H - Operator 4

ET - 06 (5)H LAP SPLICE JOINT INSPECTION
06/95

ET-06 (5)J CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Simulated Aircraft Fuselage Curvature (75 " radius)
NDE PROCEDURE:	Eddy Current - Contract Probe 250kHz nominal J1 &J1R(NDT-19) J2&J3 (MIZ-20) and J4 = 460kHz, Rotating probe
ARTIFACT TYPE:	Fatigue Cracks ~ grown in subscale and full scale panels (bending and tension) using a tension loading fixture
ARTIFACT SHAPE:	ASPECT RATIO - 1.0 (a/c) corner cracks at chamfer
ARTIFACT VERIFICATION:	Optical comparator with a video based microscope
MATERIAL:	2024 Aluminum T-37
TEST OBJECT THICKNESS:	0.040 to 0.040 inch thick, lap splice configuration
TEST OBJECT CONDITION:	As grown in completed (riveted panels) ——————**PAINTED**
SURFACE FINISH:	Aircraft Skin - representative of good mill practices
APPLICATION:	**Manual scan with a template and rotating probe --NOTE: Manual scan with a template is the "Calibration" at 0.100" (Elotest - B1) recommended validation procedure.**
DATA SET IDENTIFIER:	ETAAFJ-1; J-1R: J-2; J-3, and J-4
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	184 Cracks (782 Opportunities)
DETECTED:	J-1 = 117; J-1R = 136; J-2 = 117; J-3 = 140, and J-4 = 138
FALSE CALLS:	J-1,1 = 0.13%; J-1R,11 = 1.41%; J-2.25 = 3.2%; J-3,3 = 0.38% and J-4,0
REFERENCE:	DOT/FAA/CT-92/12,III Spencer, Floyd and Donald Schurman, **Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment**, May 1995
DATE:	Final Report
WORK SPONSOR:	Dr. Christopher Smith, FAA Technical Monitor
PERFORMING ORGANIZATION	Aging Aircraft NDI Validation Center established at Sandia National Laboratories (SNL) Albuquerque, New Mexico
NOTES:	This program was performed in support of the FAA Aging Aircraft Program and was designed to provide a baseline NDI capabilities assessment at Airline facilities.
	Test panels were designed to simulate the Boeing 737 lap splice joint and inspection procedures used at Airline facilities were based on recommended Boeing procedures.



The results are intended to be representative of typical fastener hole (filled) inspection being performed at Airline facilities.	
The original data analysis was based on a modified log logistic model to incorporate a background miss rate that is independent of crack size. [REF. 5]	
90% POD Length -	"AS PRODUCED"
J1= 0.101 in. (2.57 mm)	
J1R= 0.094 in. (2.40 mm)	
J2= 0.145 in. (3.68 mm)	
J3= 0.080 in. (2.03 mm)	
J4= 0.101 in. (2.55 mm)	

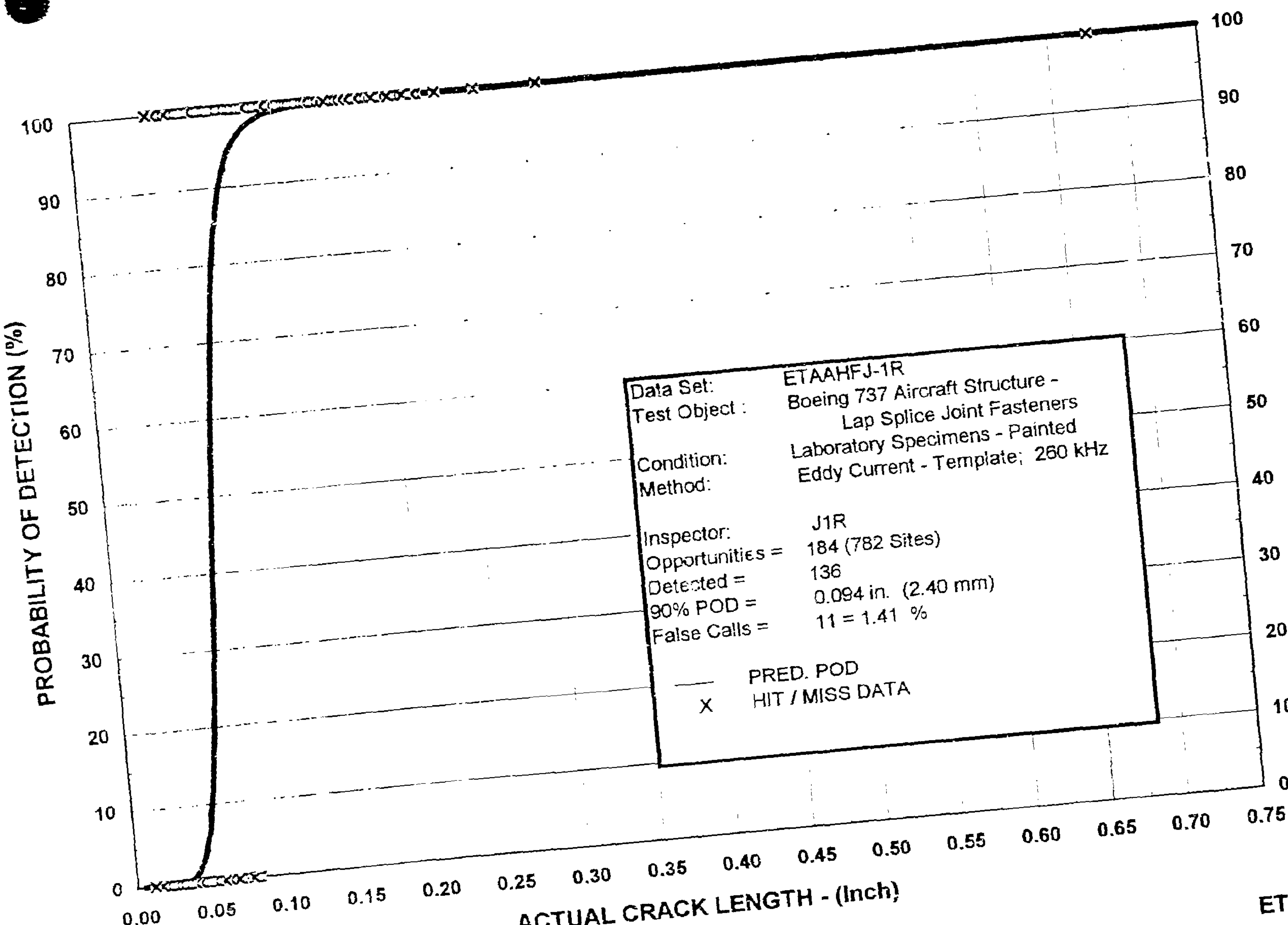


ET - 06 (5)J LAP SPLICE JOINT INSPECTION

06/95

ETAAHFJ-1

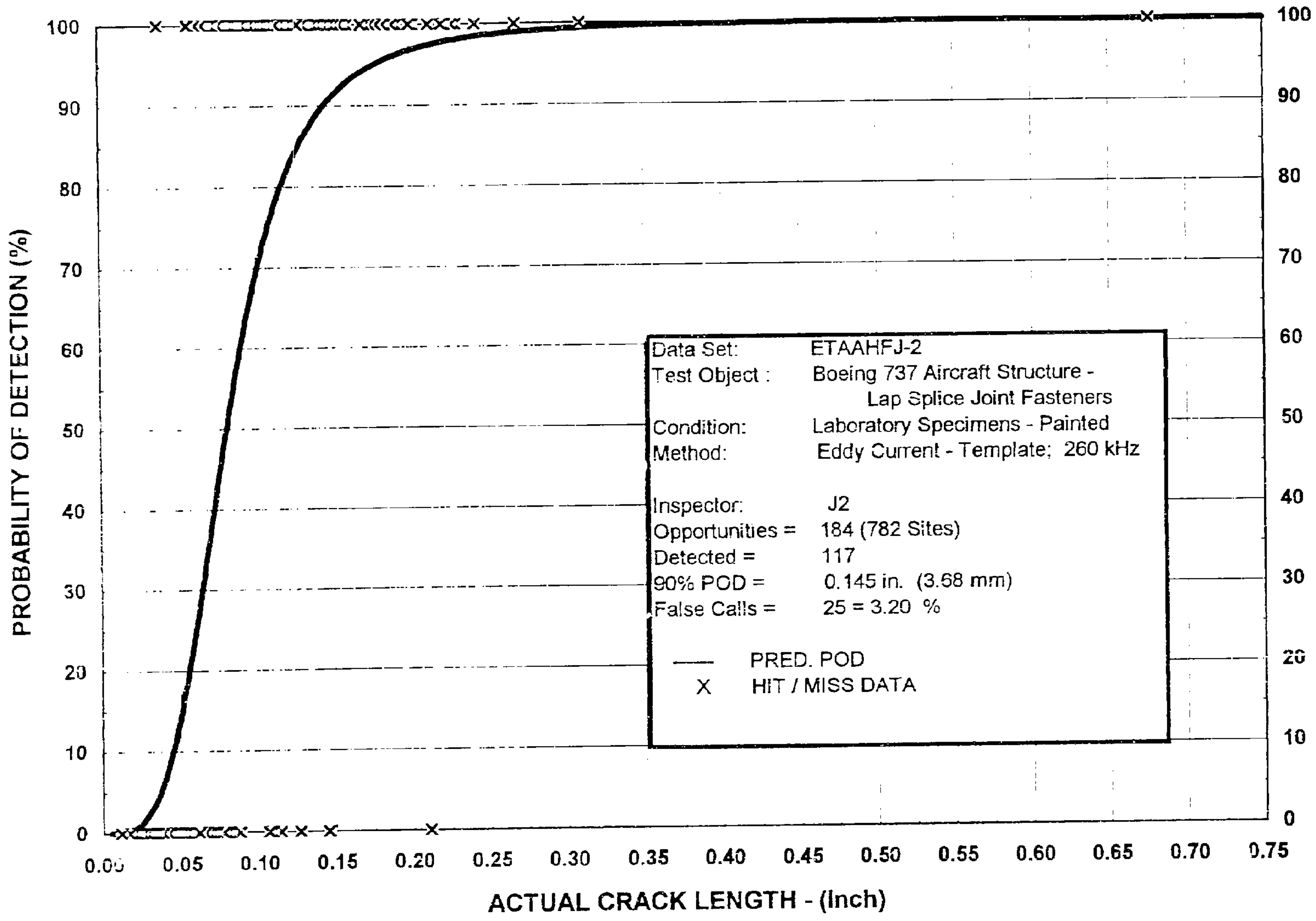
Facility J - Operator 1



ETAAHFJ-1R
Facility J - Operator 1 / REPEAT

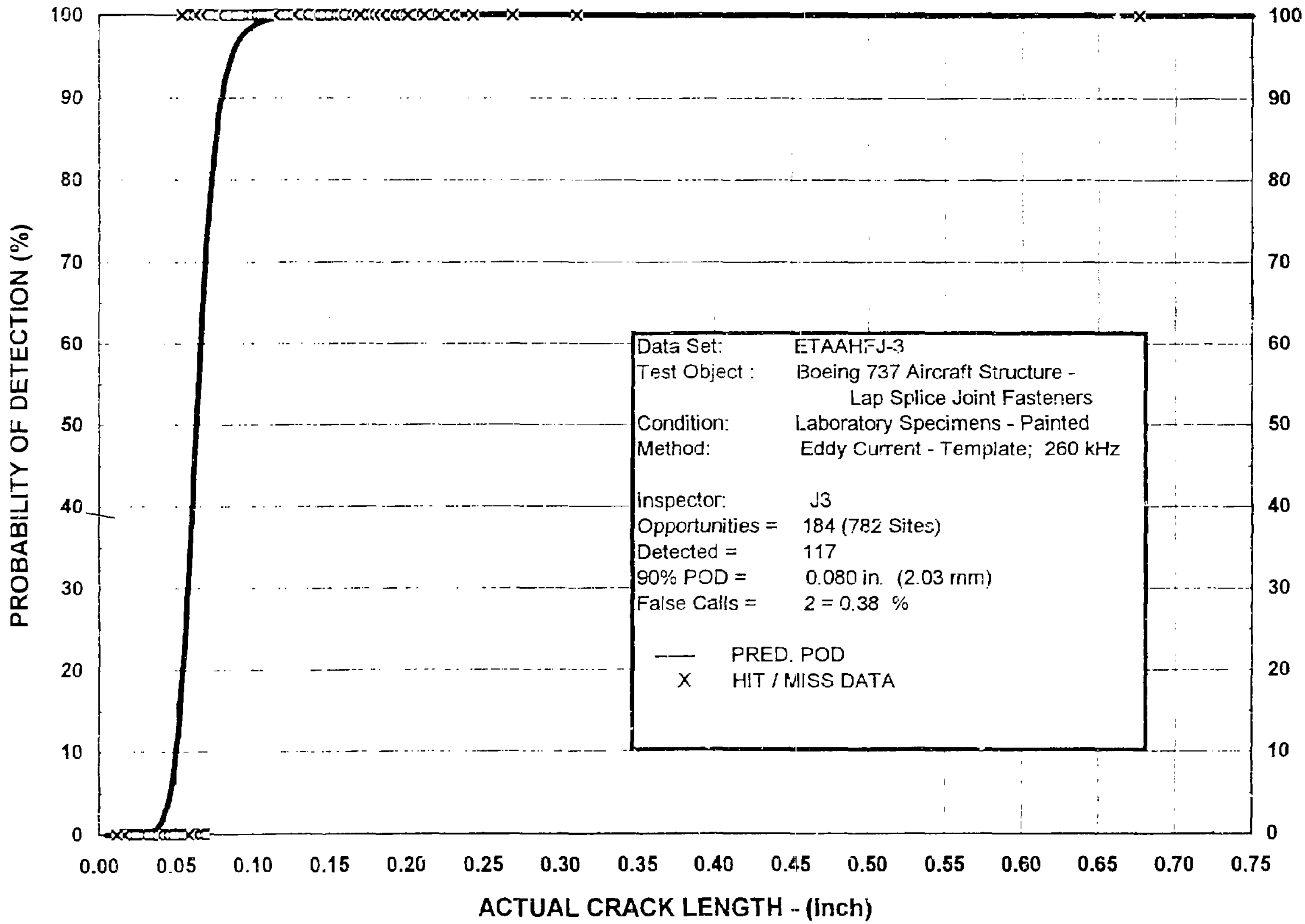
ET - 06 (5)J LAP SPLICE JOINT INSPECTION

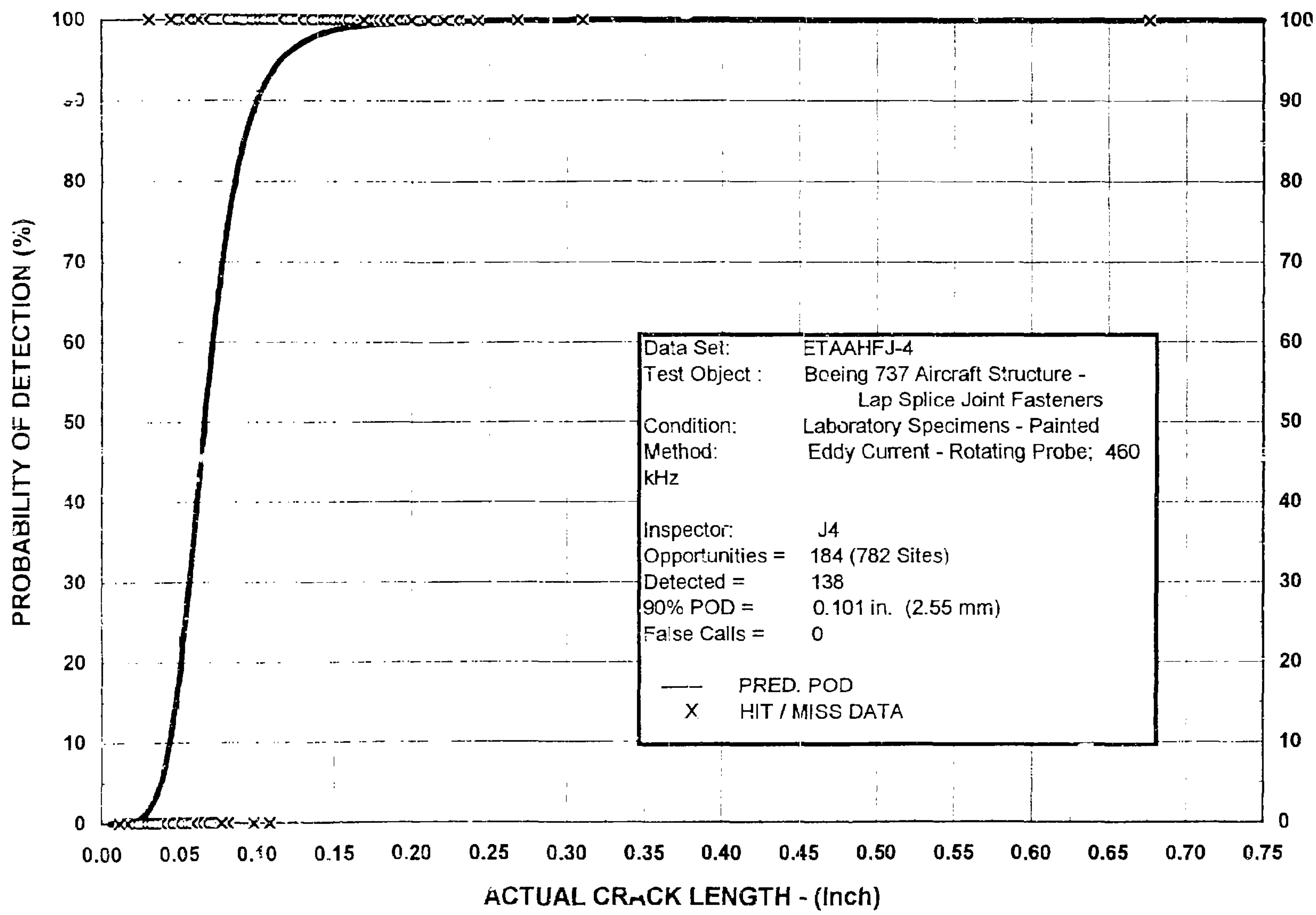
06/95



ETAAHFJ-2
Facility J - Operator 2

ET - 06 (5)J LAP SPLICE JOINT INSPECTION
06/95

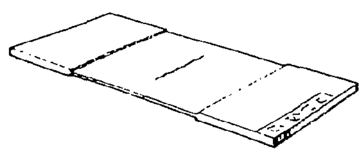

PROBABILITY OF DETECTION (%)
0
10
20
30
40
50
60
70
80
90
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
ACTUAL CRACK LENGTH - (Inch)
Data Set: ETAAHFJ-3
Test Object : Boeing 737 Aircraft Structure - Lap Splice Joint Fasteners
Condition: Laboratory Specimens - Painted
Method: Eddy Current - Template; 260 kHz
Inspector: J3
Opportunities = 184 (782 Sites)
Detected = 117
90% POD = 0.080 in. (2.03 mm)
False Calls = 2 = 0.38 %
PRED. POD
X HIT / MISS DATA



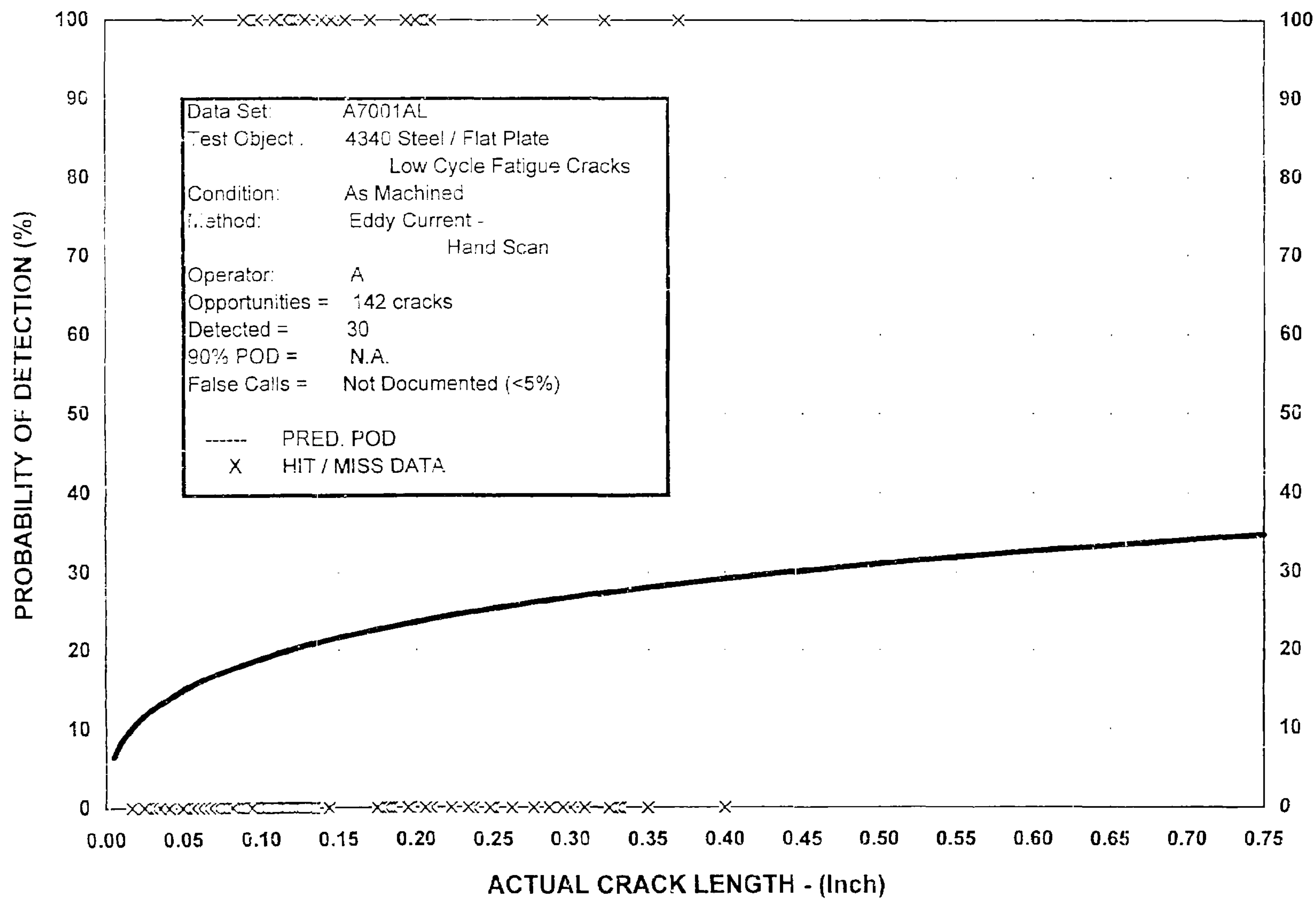
ETAAHFJ-4
Facility J - Operator 4

ET - 06 (5)J LAP SPLICE JOINT INSPECTION
06/95

A7000(2)L	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Eddy Current - Contact probe: 3 MHz, Meter read-out
ARTIFACT TYPE:	Fatigue Cracks - R< 0 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,B1"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	A7001-A,B,C; A7003-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	176 Cracks -Variation in the number inspected during each sequence
DETECTED:	A7001 - A = 30/142, B=20/142, C= 16/142; A7003 - A= 64/176, B= 50/176, C= 68/176
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



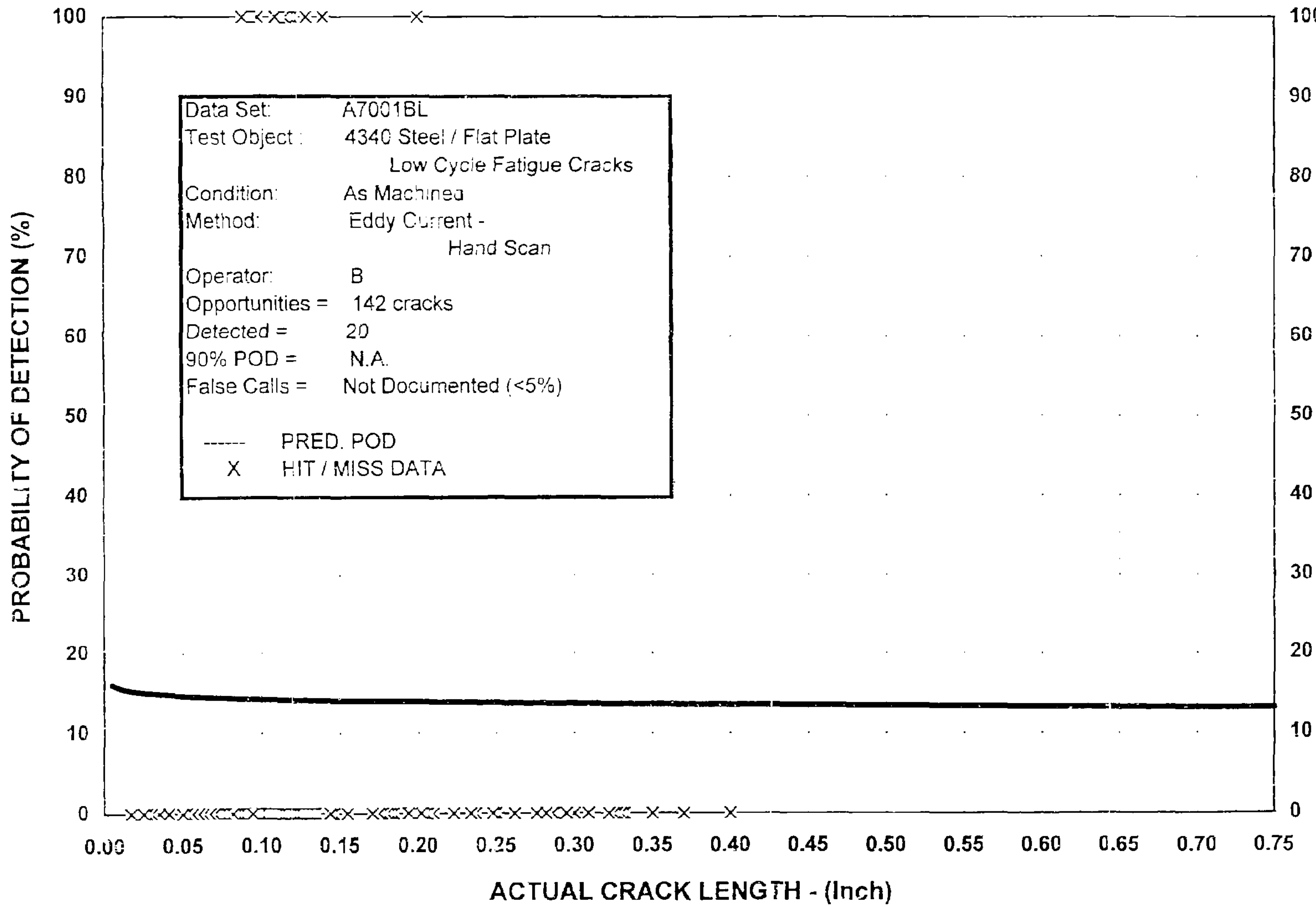
90% POD	"AS MACHINED"	"AFTER PROOF"
	A= Not Achieved	A= Not Achieved
	B=Not Achieved	B= Not Achieved
	C= Not Achieved	C= Not Achieved



A7001AL
AS MACHINED - OPERATOR A

A7000(2) EDDY CURRENT INSPECTION OF 4340 STEEL PANELS

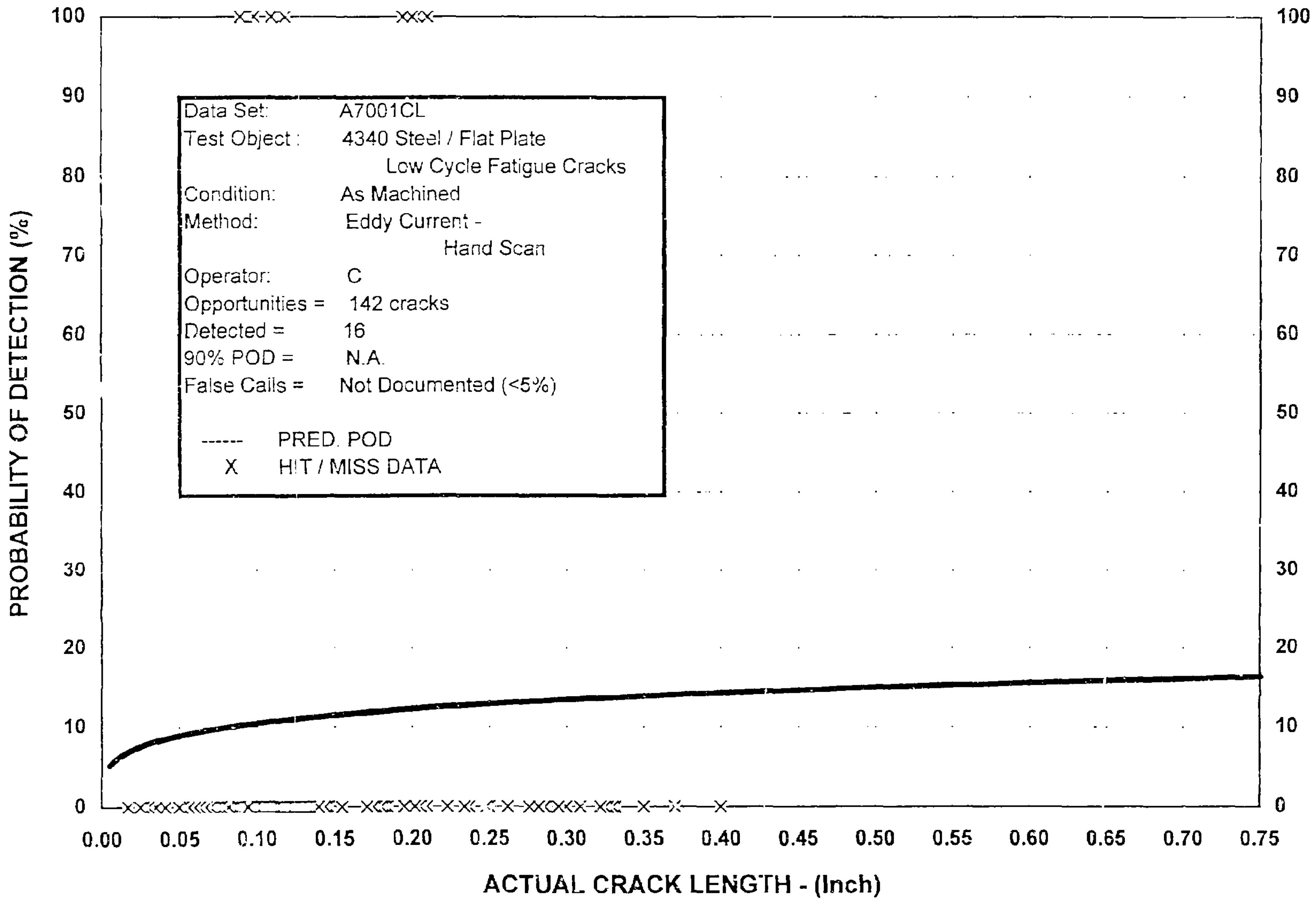
9/96 - A7001AL



A7001BL
AS MACHINED - OPERATOR B

A7000(2) EDDY CURRENT INSPECTION OF 4340 STEEL PANELS

9/96 - A7001BL

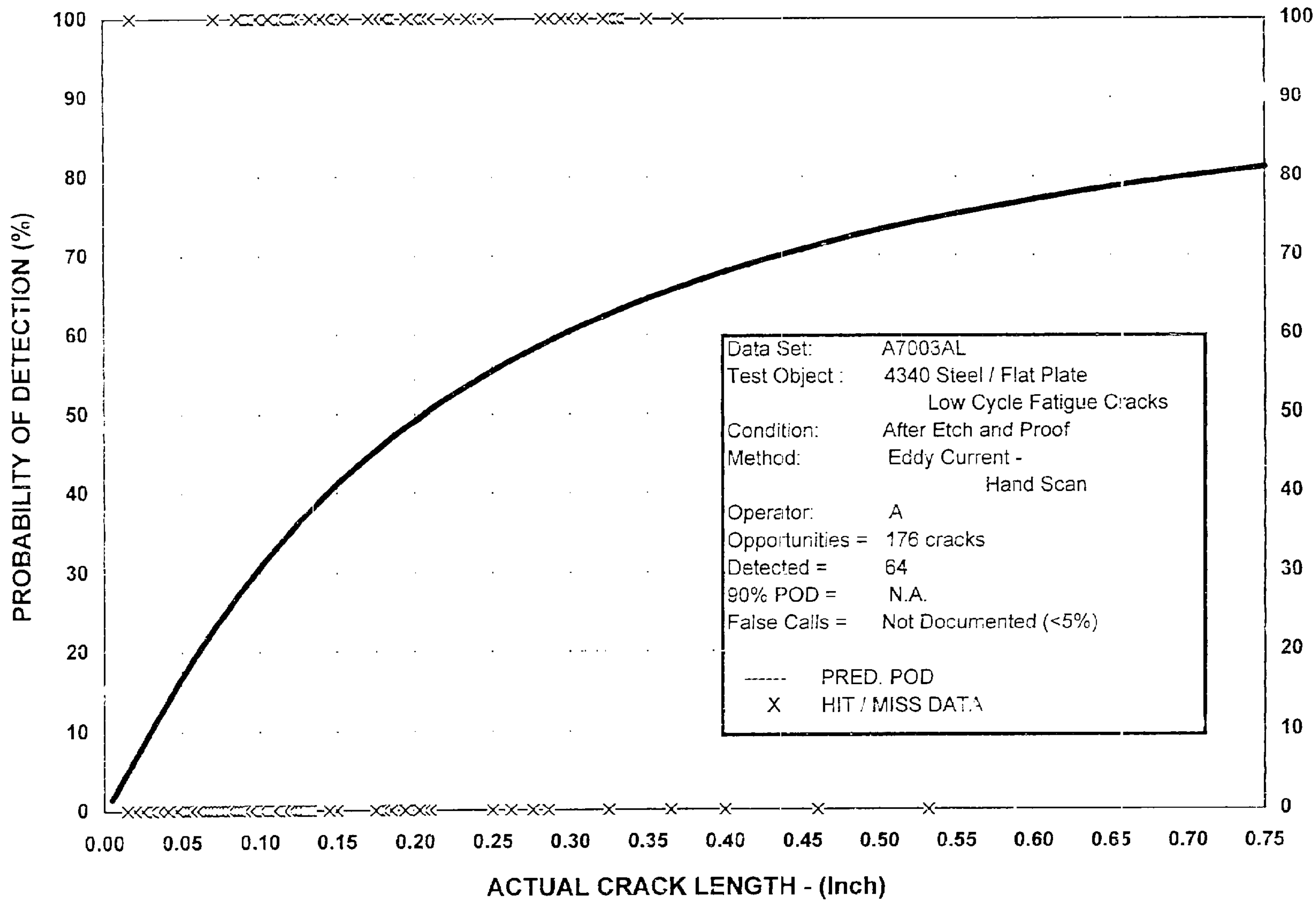


A7001CL

AS MACHINED - OPERATOR C

A7000(2) EDDY CURRENT INSPECTION OF 4340 STEEL PANELS

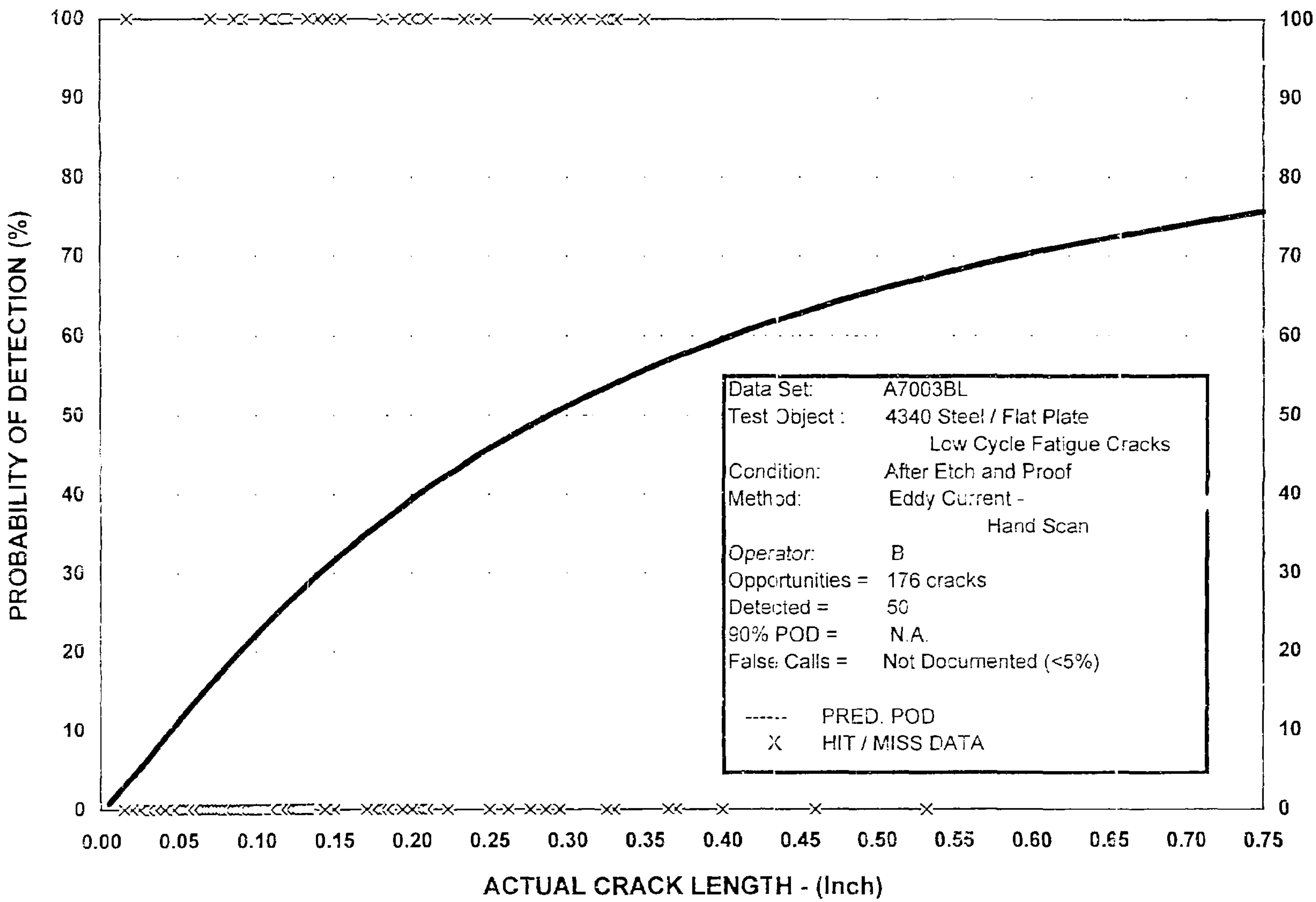
9/96 - A7001CL



A7000(2) EDDY CURRENT INSPECTION OF
4340 STEEL PANELS

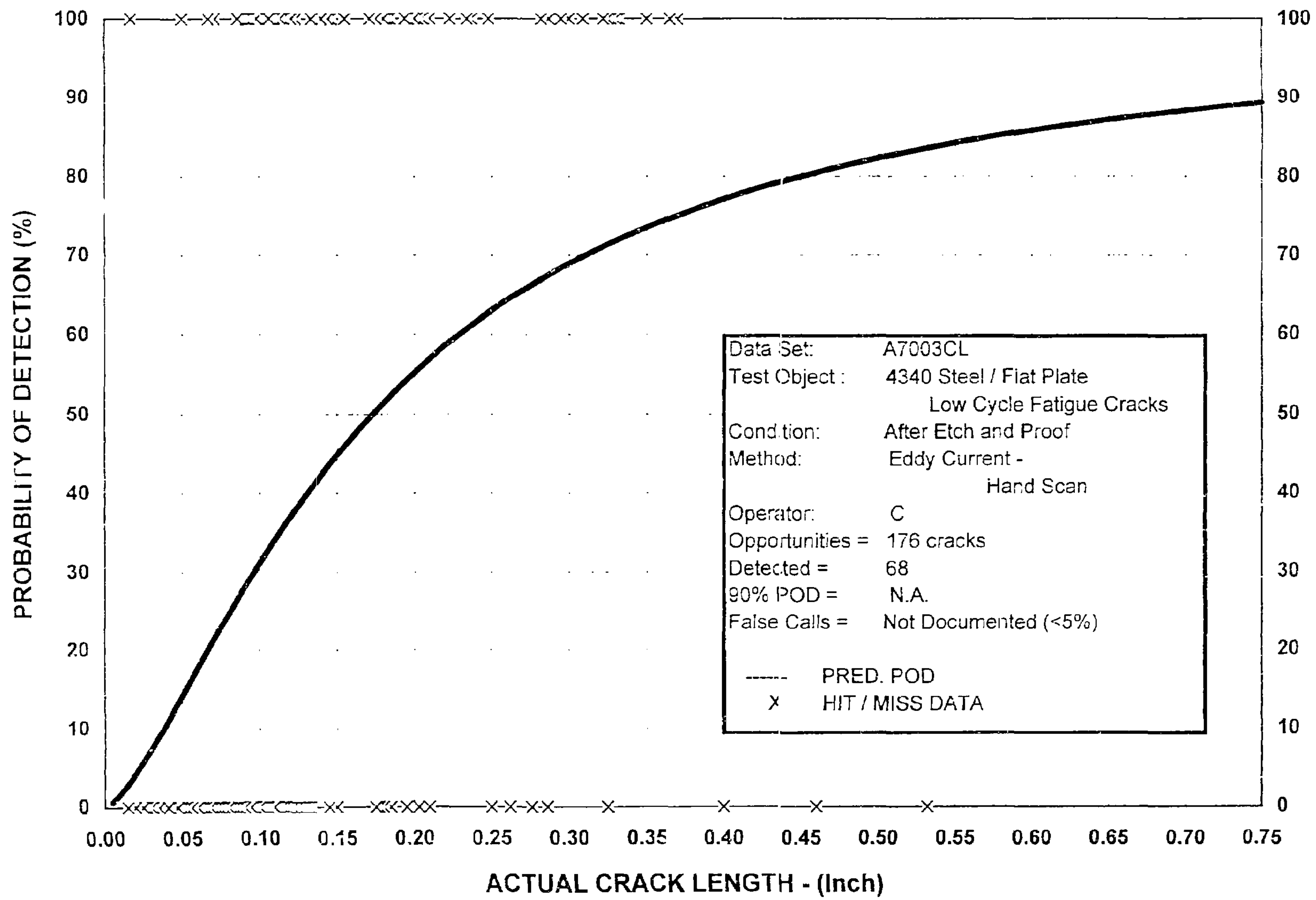
9/96 - A7003AL

A7003AL
AFTER ETCH AND PROOF OPERATOR A



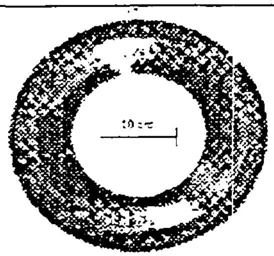
A7003BL
AFTER ETCH AND PROOF
OPERATOR B

A7000(2) EDDY CURRENT INSPECTION
OF 4340 STEEL PANELS
9/96 - A7003BL

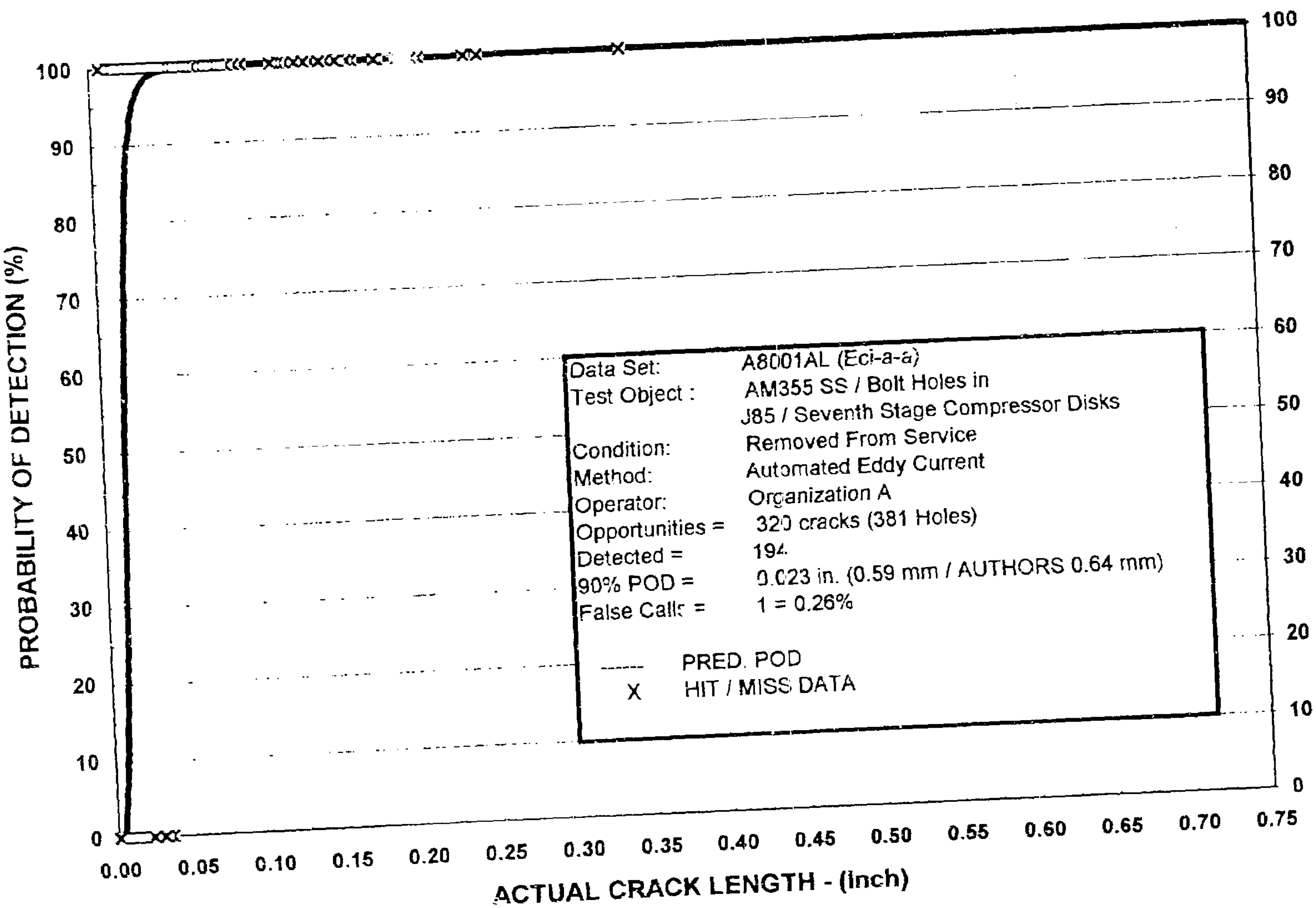


A7000(2) EDDY CURRENT INSPECTION
OF 4340 STEEL PANELS
9/96 - A7003CL

A7003CL
AFTER ETCH AND PROOF
OPERATOR C

A8000(7)L	DATA SET DESCRIPTION
METHOD:	Eddy Current
TEST OBJECT TYPE:	Bolt holes in J85 / Seventh stage compressor disks; 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Eddy Current, Bolt Holes - Automatic and Manual
ARTIFACT TYPE:	*Service induced fatigue cracks*
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Automated Inspection / Automated Recording and Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	A8001L; A8002L; A8003L; A8004L; A8005L; and A8006L
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	381 Holes / 320 cracks
DETECTED:	A8001L - 194; A8002L -284; A8003L - 252; A8004L - 184; A8005L - 183; and A8006L -145
FALSE CALLS:	A8001L - 1; A8002L - 27; A8003L - 9; A8004L - 1; A8005L - 2; and A8006L - 0
REFERENCE:	LTR-ST-2055, D.S. Forsyth and A. Fahr, **The Sensitivity and Reliability of NDI Techniques for Gas Turbine Components Inspection and Life Prediction.**
DATE:	August, 1996.
WORK SPONSOR:	Department of National Defence, DAS Eng 6-2.
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	The maximum likelihood method of curve fitting used in this databook differs slightly from the algorithm used by the authors. The authors calculated values are shown for reference.
	Maximum differences are shown for those data sets with the greatest variance. The authors noted difficulties fitting such data to the model.
	90% POD ORG A: 0.023 in. (0.59 mm / Authors - 0.64 mm) - Automated Eddy Current
	ORG B: 0.009 in. (0.228 mm / Authors -0.31mm) - Automated Eddy Current at 0.5 Thresh.
	ORG B: 0.010 in. (0.25 mm / Authors - 0.42 mm) - Automated Eddy Current at 0.8 Thresh.
	ORG A: 0.030 in. (0.751 mm / Authors - 0.81 mm) - Auto. EC with Pattern Recognition
	ORG A: 0.029 in. (0.745 mm / Authors - 0.80 mm) - Manual Eddy Current
	ORG C: 0.036 in. (0.92 mm / Authors - 0.99 mm) - Manual Eddy Current

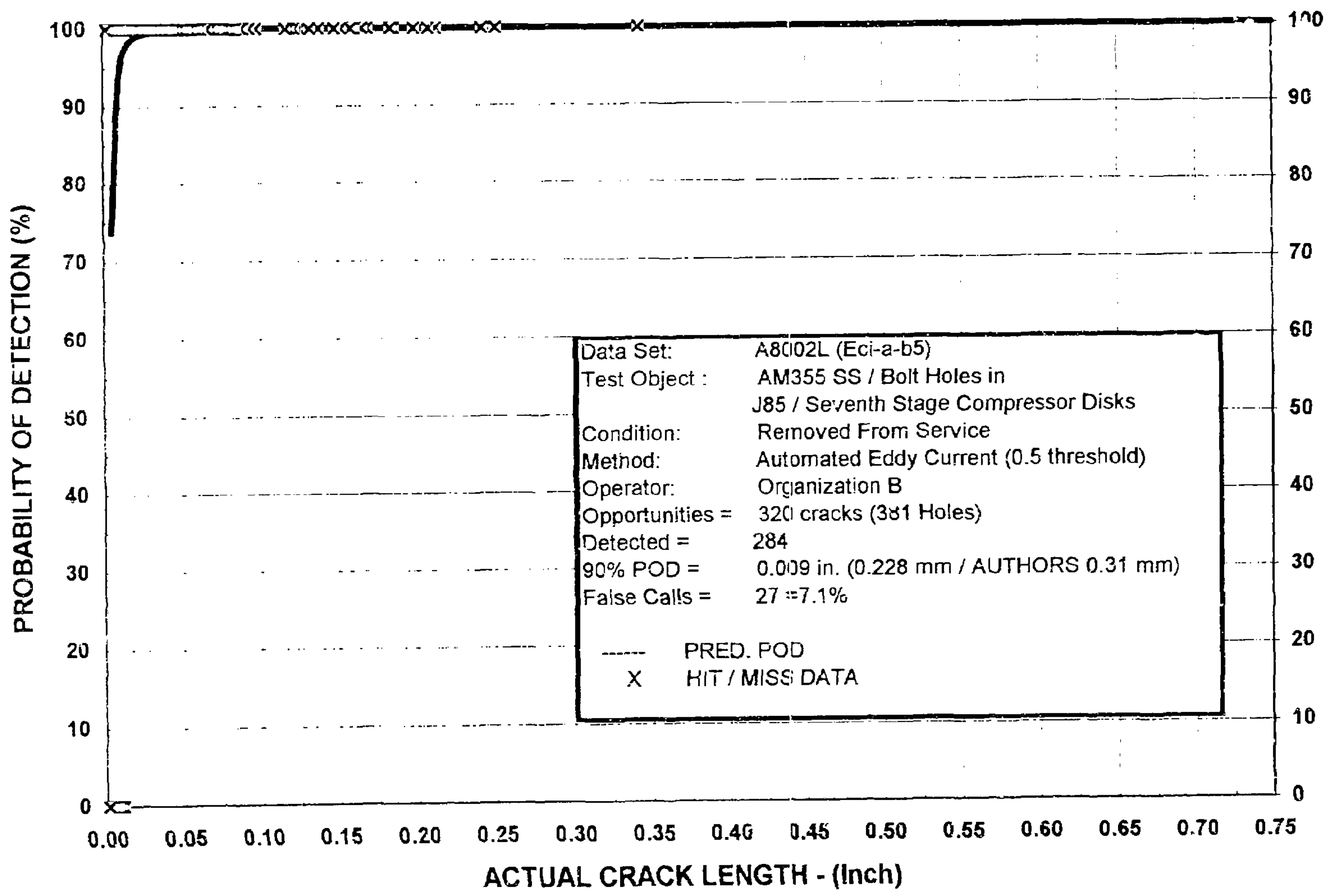
AUTOMATED AND MANUAL EDDY CURRENT INSPECTION OF GAS TURBINE ENGINE COMPRESSOR DISKS



A8001L Service Induced Cracks
- ORGANIZATION A

A8000(7) AUTOMATED EDDY CURRENT INSPECTION OF BOLT HOLES

9/96 - A8001L

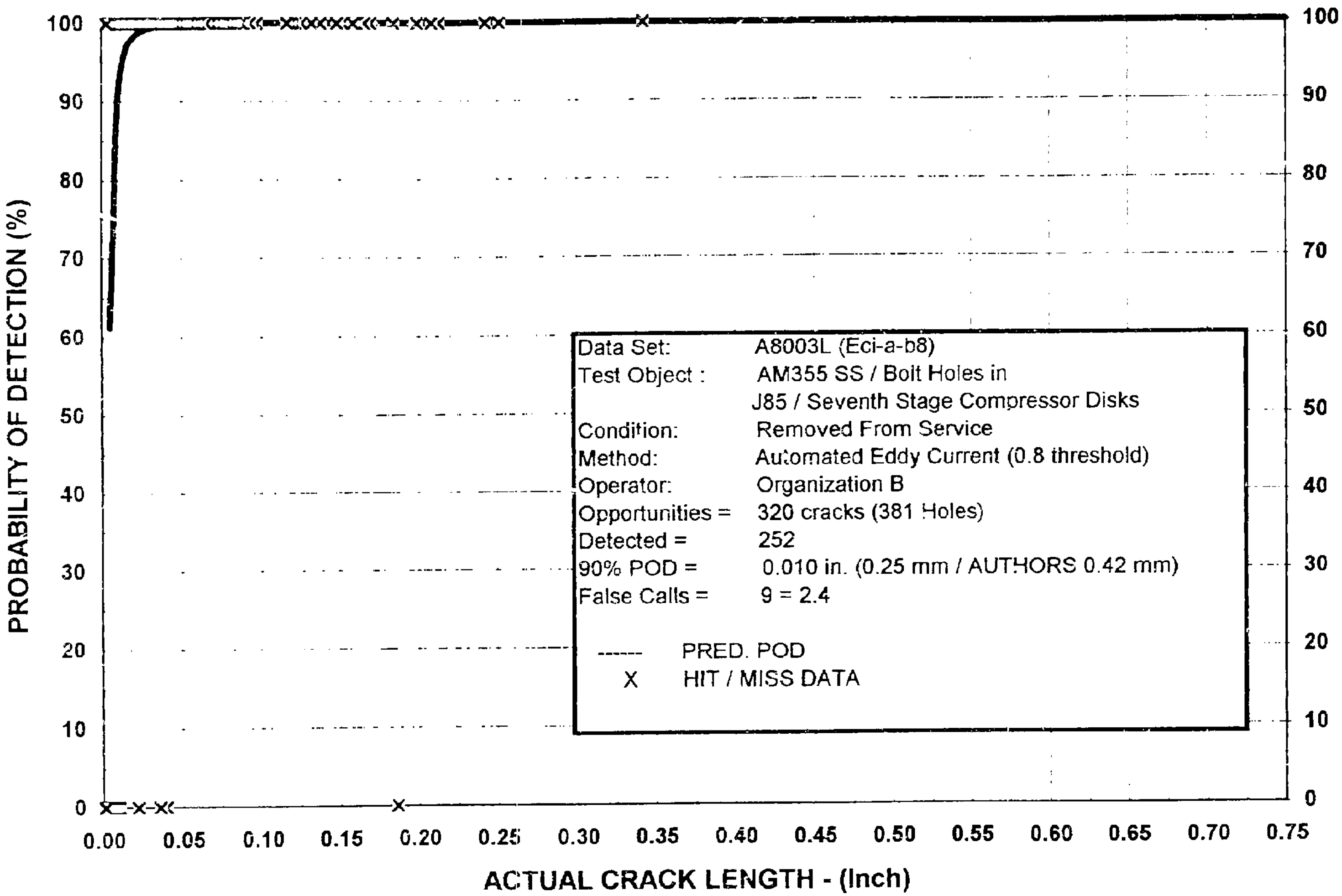


A8002L Service Induced Cracks
- ORGANIZATION B at 0.5 threshold

A8000(7) AUTOMATED EDDY CURRENT INSPECTION OF BOLT HOLES

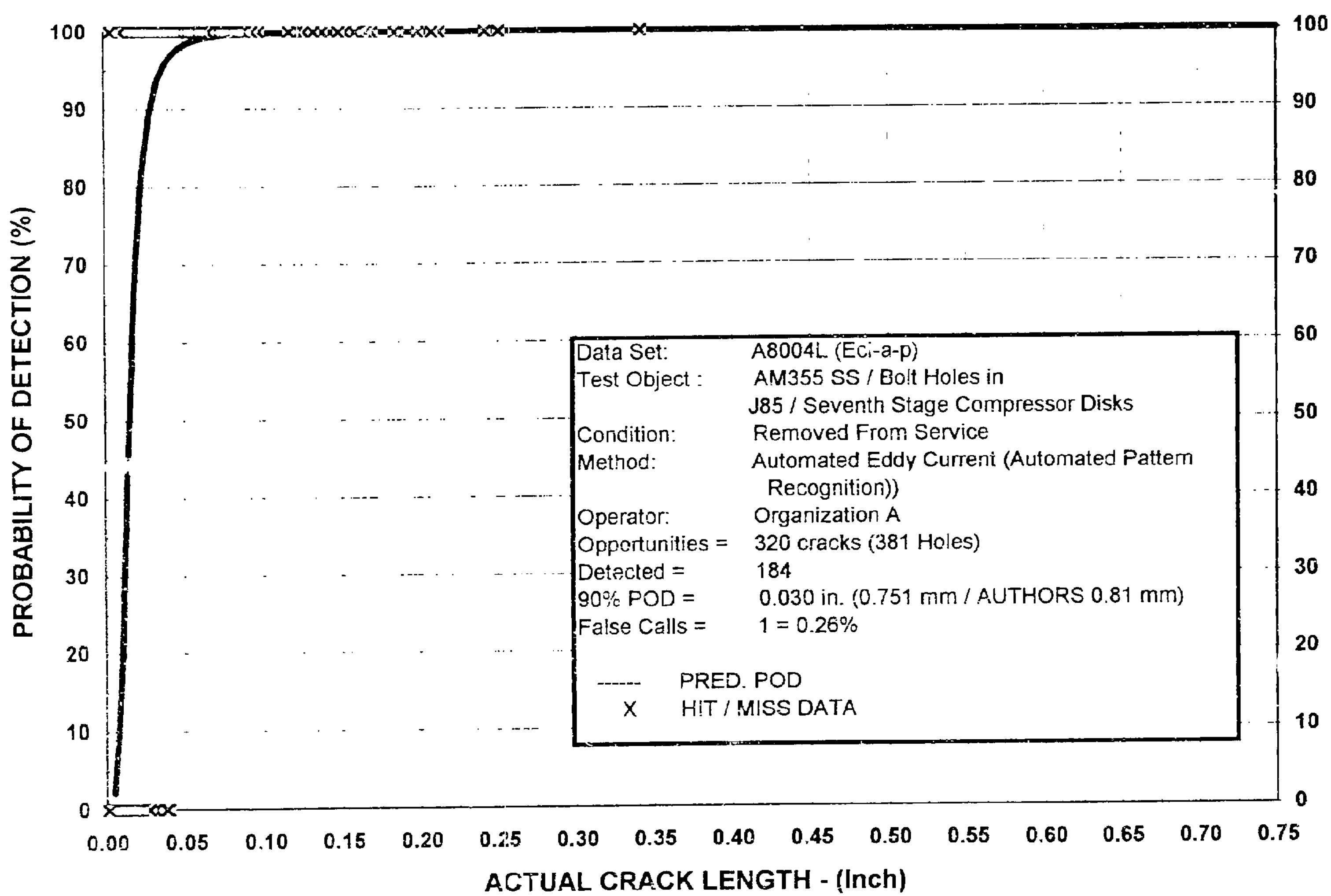
9/96 - A8002L

A8003L Service Induced Cracks
- ORGANIZATION B at 0.8 threshold



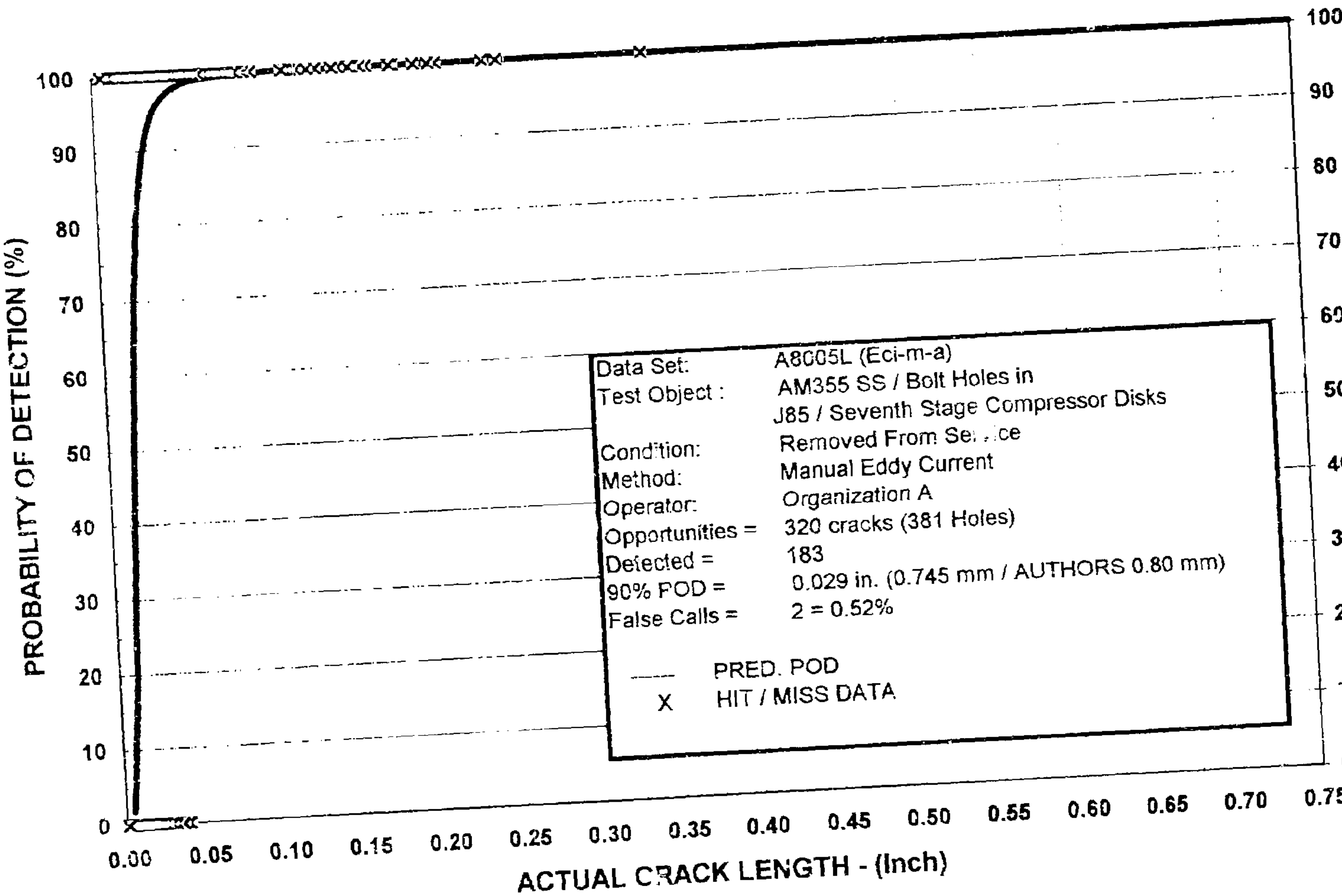
A8000(7) AUTOMATED EDDY CURRENT INSPECTION OF BOLT HOLES

9/96 - A8003L



A8004L Service Induced Cracks
ORGANIZATION A
Automated Pattern Recognition

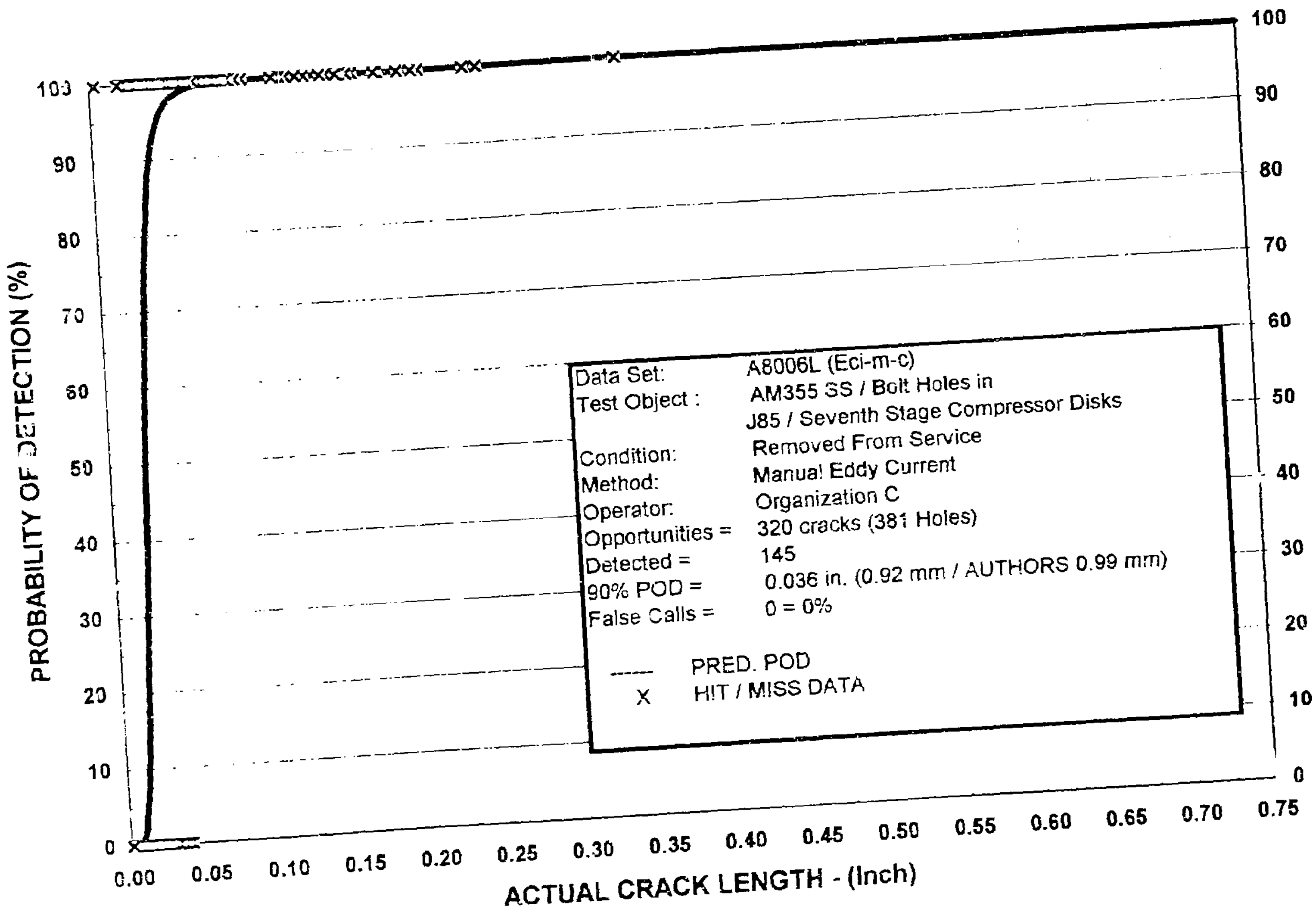
A8000(7) AUTOMATED EDDY CURRENT INSPECTION OF BOLT HOLES



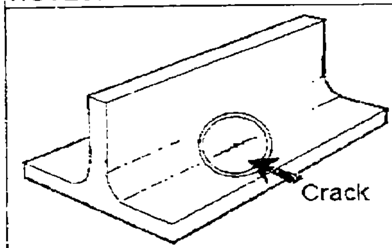
A8005L Service Induced Cracks
ORGANIZATION A
MANUAL INSPECTION

A8000(7) EDDY CURRENT INSPECTION OF BOLT HOLES

9/96 - A8005L



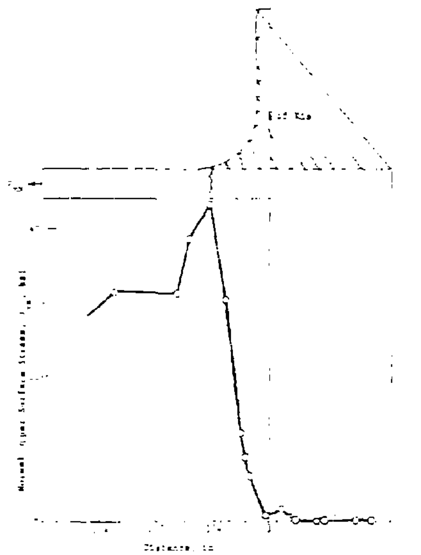
A8006L Service Induced Cracks
ORGANIZATION C
MANUAL INSPECTION

A9000(3)L,D	**DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS**
METHOD:	Eddy Current
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (A9001 and A9002); Stringers Riveted to a Flat Plate (A9003)
NDE PROCEDURE:	Eddy Current - Contact Probe 100 kHz, 0.063 in. core, pencil probe; hand scan with tooling aid.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	Base Plate- 0.250 inch nominal / Webs - 0.250 inch nominal
TEST OBJECT CONDITION:	A9001,"As Machined"; A9002,"After Etch"; A9003, Stringers cut from panel and riveted to a flat plate.
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Raster scan with tooling aids
DATA SET IDENTIFIER:	A9001(3)L,D; A9002(3)L,D; A9003(3)L,D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	417 Cracks
DETECTED:	A9001(3)L/D = 256; A9002(3)L/D = 299 ; A9003(3)L/D = 209 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **<u>The Detection of Tightly Closed Flaws by Nondestructive Testing Methods</u>**. October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	146 flaws were induced in 46 panels (both sides of the web). Four blank panels; included:Total of 50panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS MACHINED" "AFTER ETCH" "RIVETED CONFIGURATION"
	A= Not Achieved A= 0.374 in. A= Not Achieved
	90% POD Depth - "AS MACHINED" "AFTER ETCH" "RIVETED CONFIGURATION"
	A= 0.119 in. A= 0.054 in. A= 0.100 in.
Test Specimen Descriptions on the following page!	

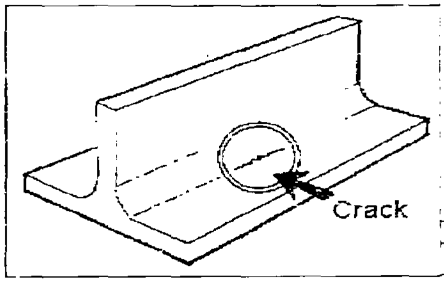
EDDY CURRENT INSPECTION OF AIRCRAFT STRINGER SHAPES

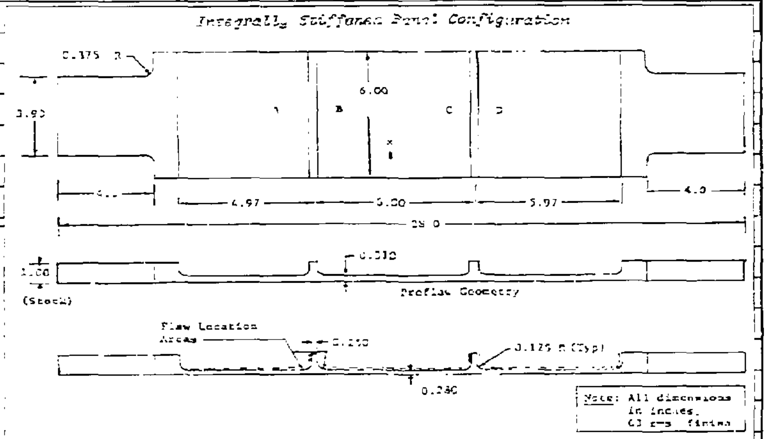
A9000(3)L	DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS
METHOD:	Eddy Current
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (A9001 and A9002); Stringers Riveted to a Flat Plate (A9003)
NDE PROCEDURE:	Eddy Current - Contact Probe 100 kHz, 0.063 in. core, pencil probe; hand scan with tooling aid.

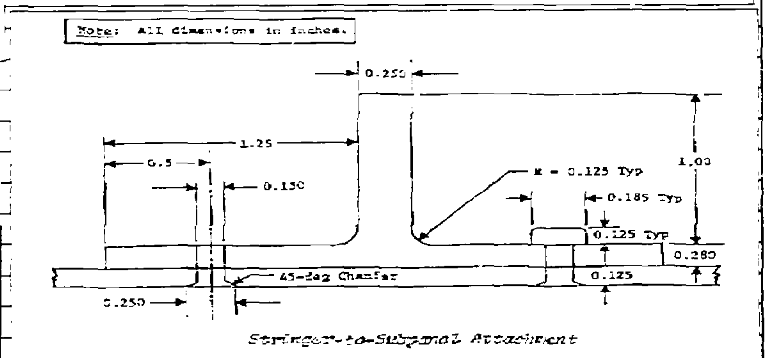
TEST SPECIMEN DESCRIPTORS

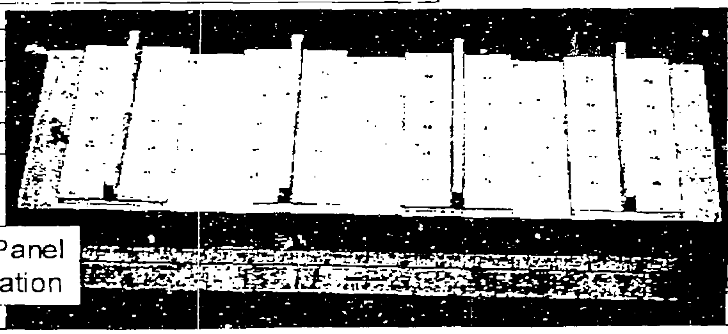


Anticipated Surface Stress Distribution for and axial load (panel plane)



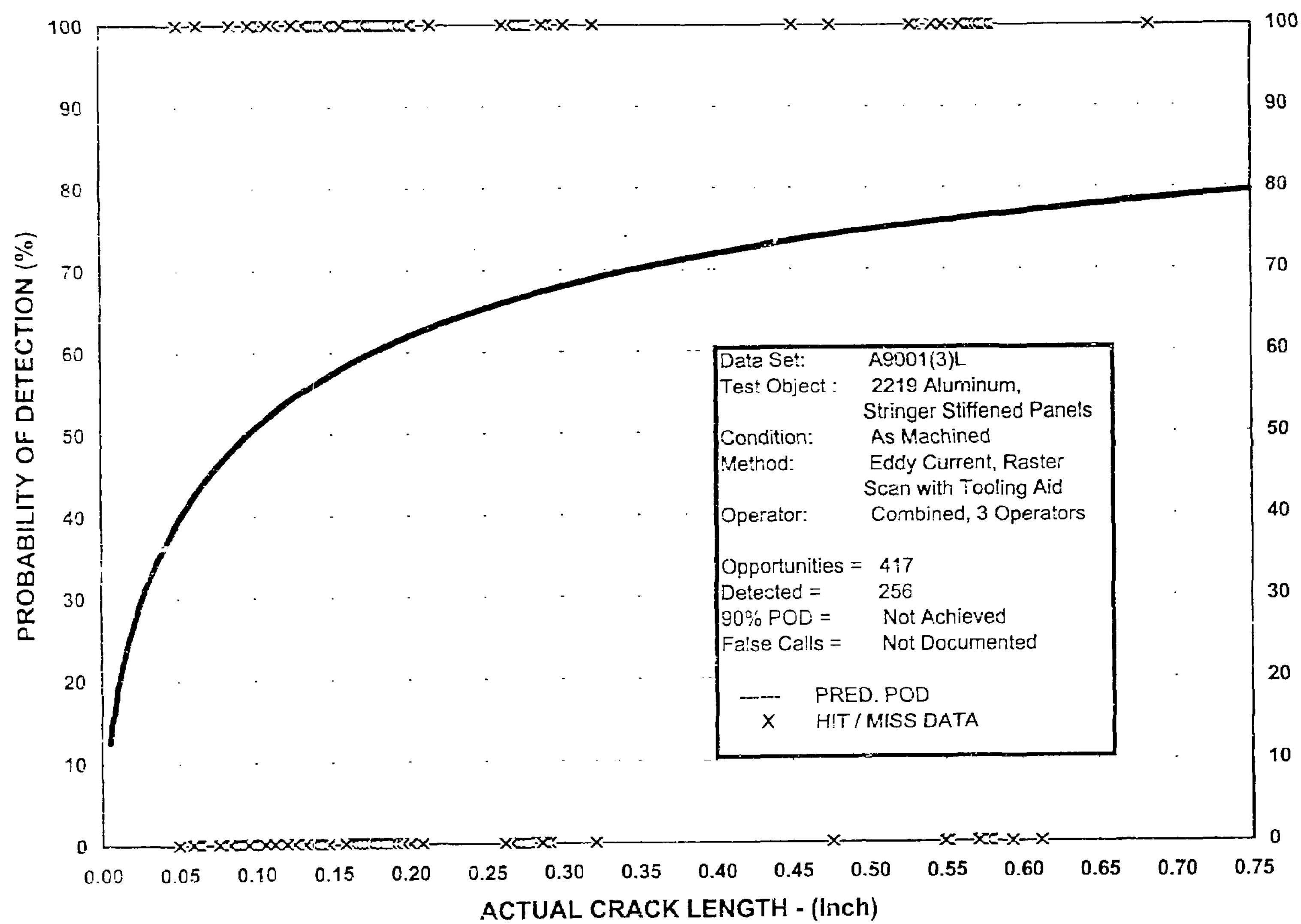






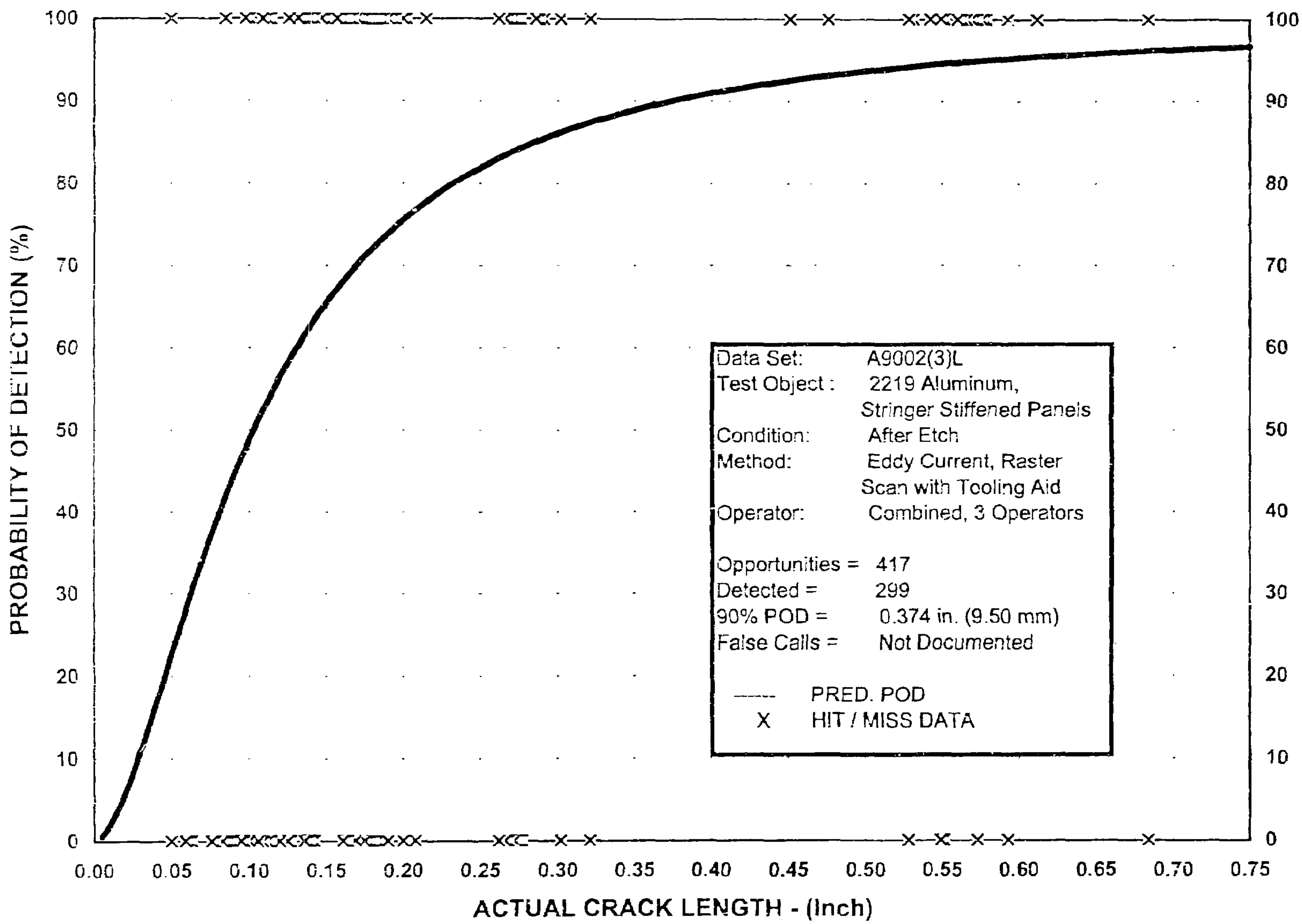
Riveted Panel Configuration

STRINGER STIFFENED PANELS AND RIVETED STIFFENERS ON A FLAT PANEL SUBSTRATE



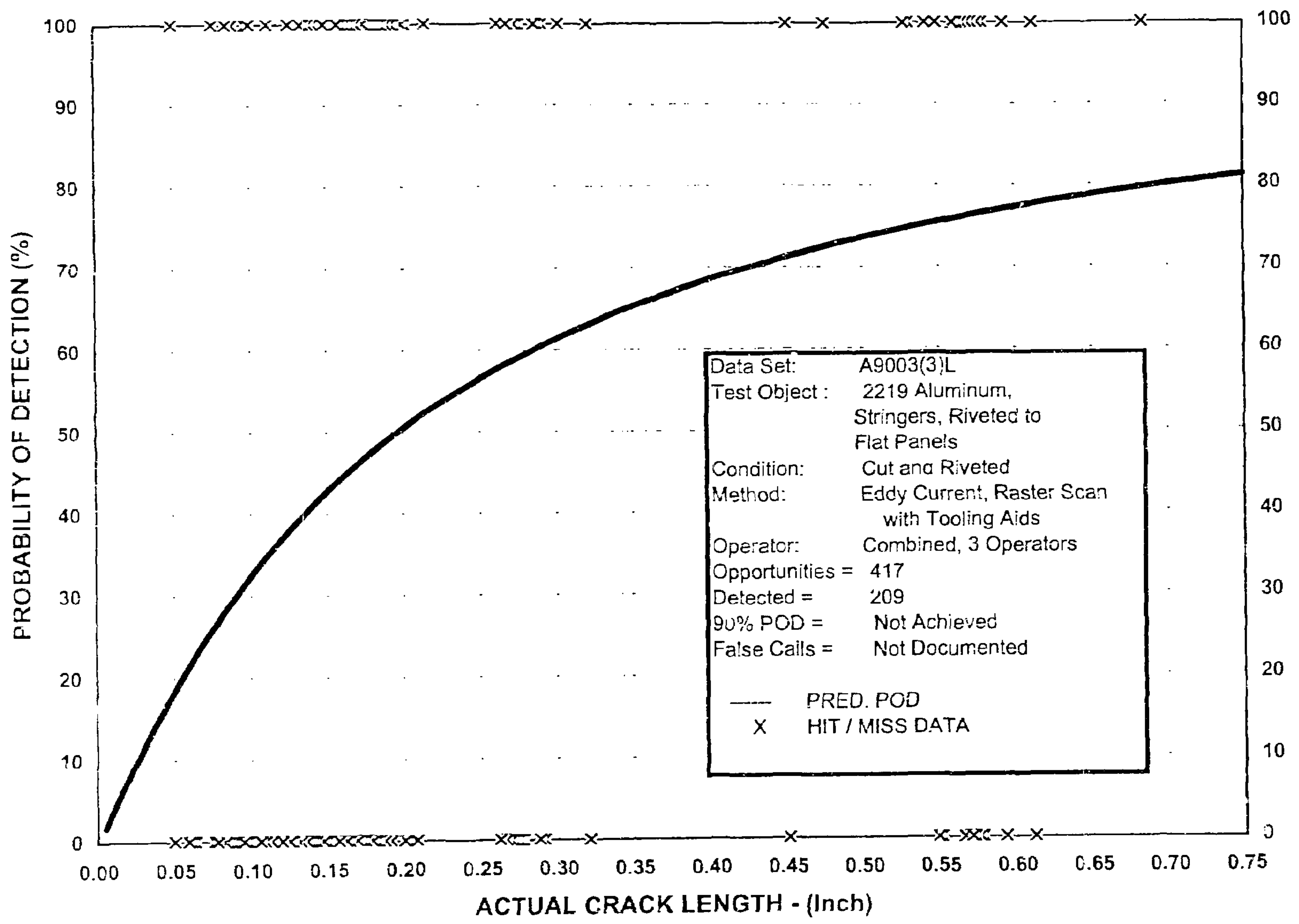
A900¹(3)L
6/97 -A9001(3)L

Eddy Current, Raster Scan with a Tooling Aid - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



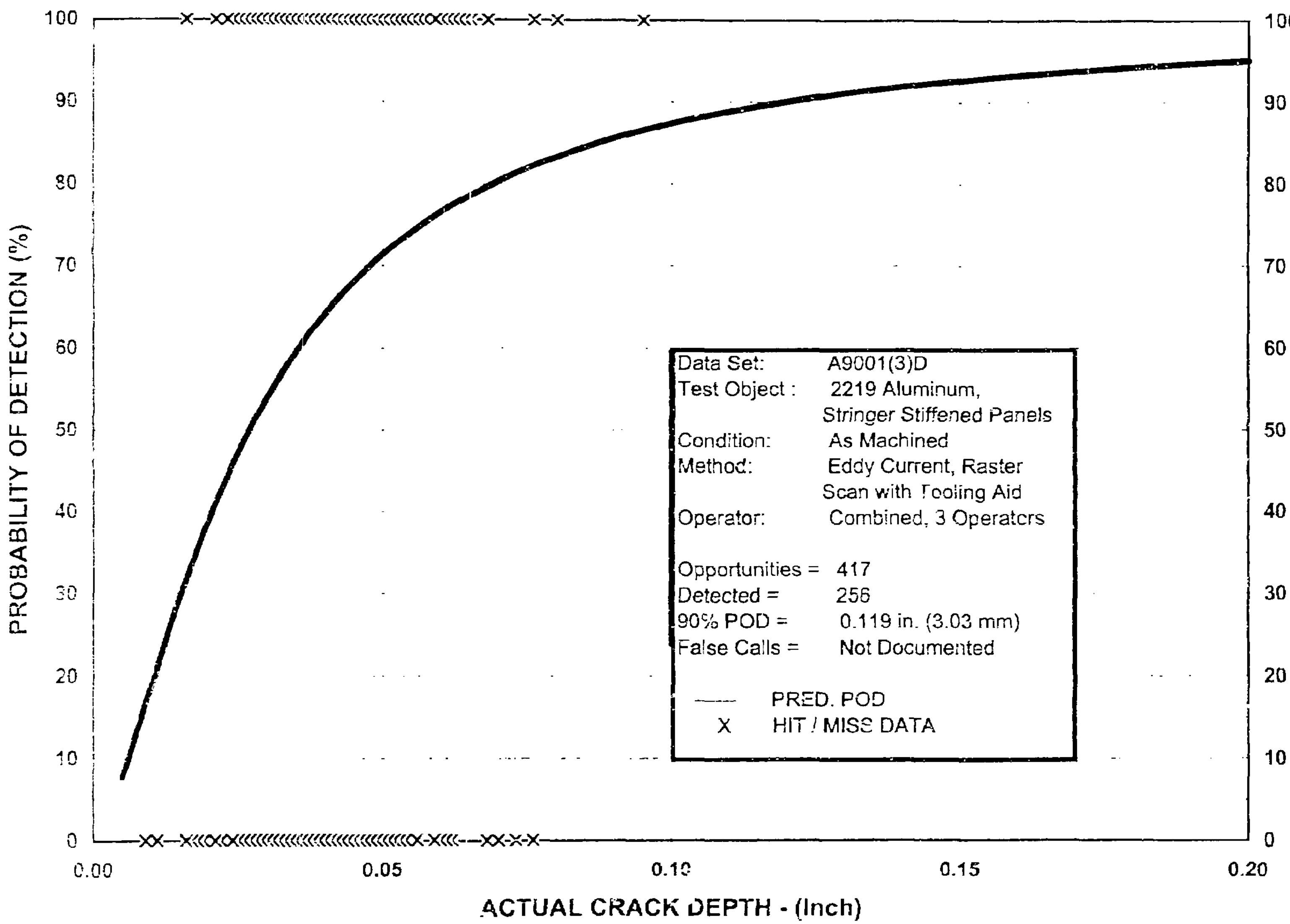
A9002(3)L
6/97 -A9002(3)L

Eddy Current, Raster Scan with a Tooling Aid - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch



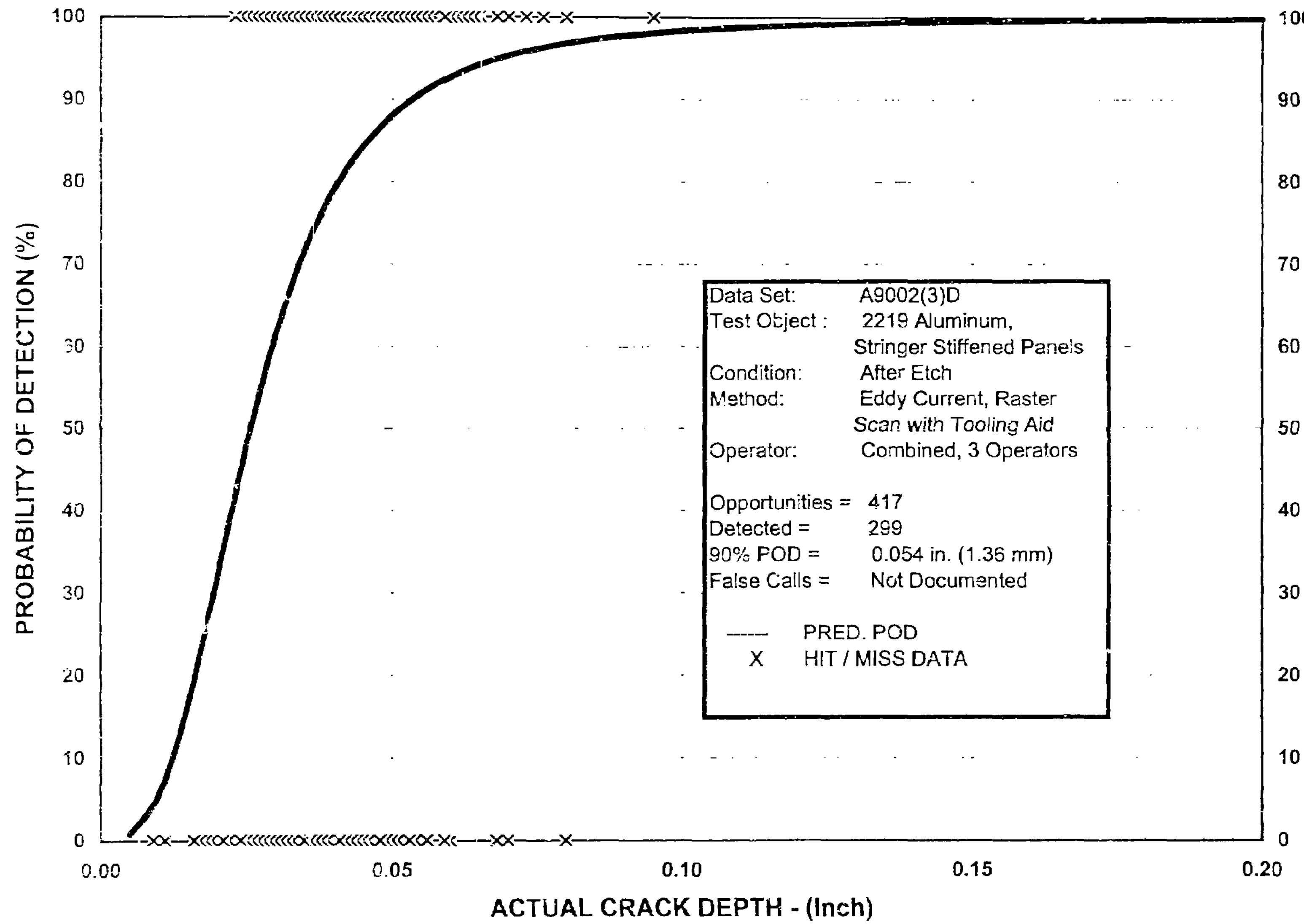
A9003(3)L
6/97 -A9003(3)L

Eddy Current, Raster Scan with a Tooling Aid- 3 Operators
2219 Aluminum, Stringers, Riveted to Flat Panels



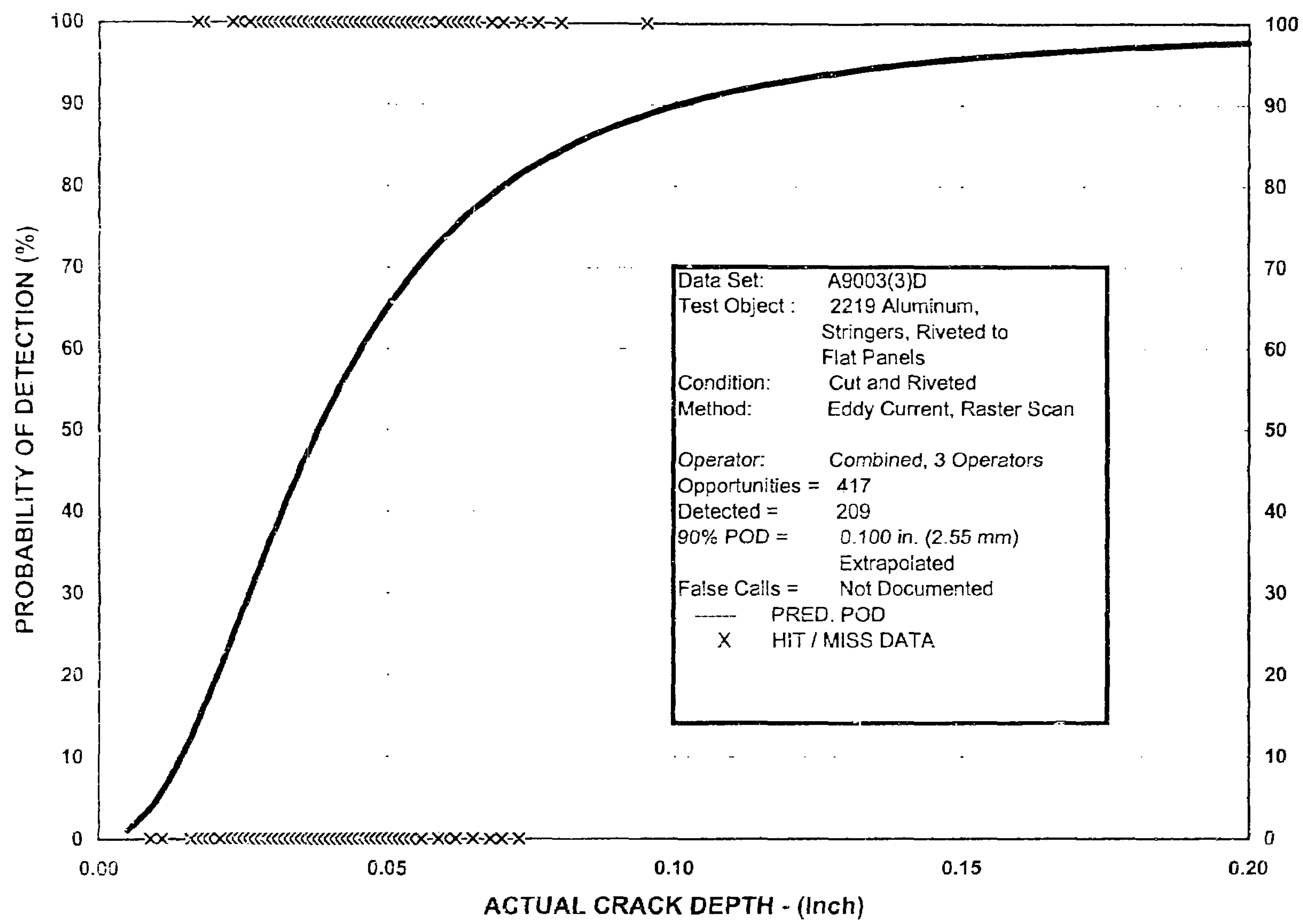
A9001(3)D
6/97 -A9001(3)D

Eddy Current, Raster Scan with a Tooling Aid - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



A9002(3)D
6'97 -A9002(3)D

Eddy Current, Raster Scan with a Tooling Aid - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch

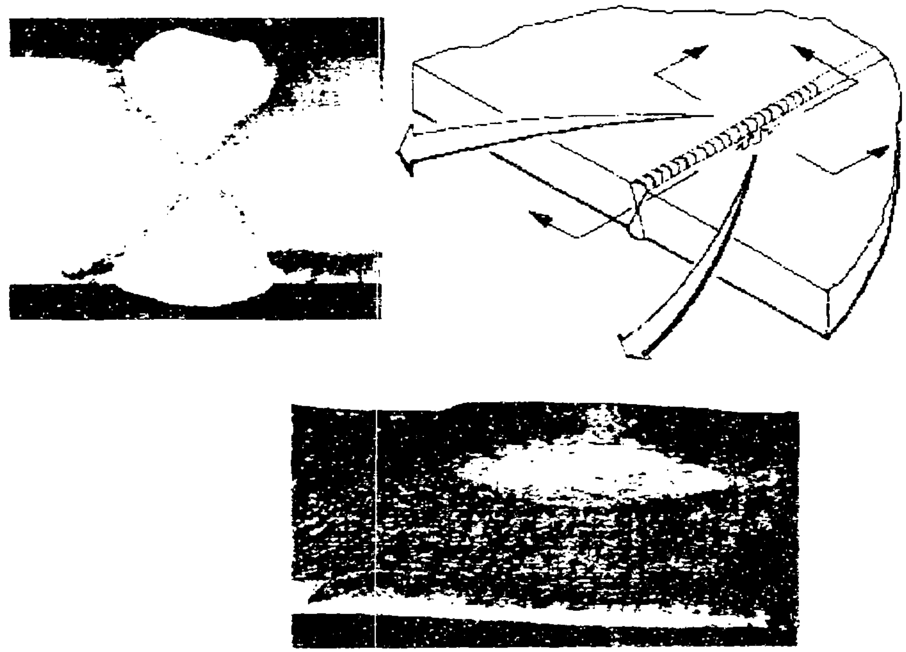


A9003(3)D
6/97 -A9003(3)D

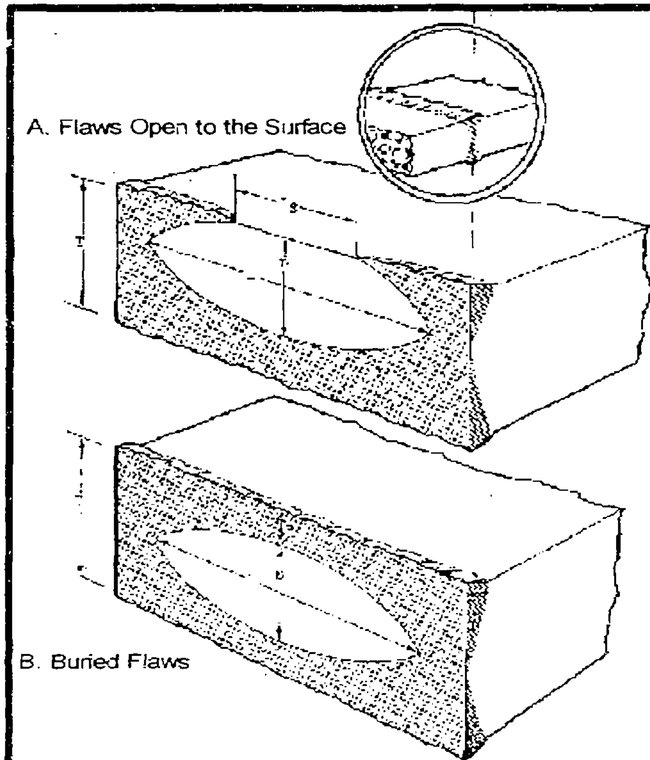
Eddy Current, Raster Scan with a Tooling Aid - 3 Operators
2219 Aluminum, Stringer, Riveted to Flat Panels

AA000(3)L	DATA SET DESCRIPTION
METHOD:	Machine scan with a contact eddy current probe; threshold gating and recording.
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. One pass from each panel surface.
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Lack of Penetration (LOP) defects / cracks, produced by the two pass weld process
ARTIFACT SHAPE:	Lune shapes with target lengths of 0.250, .500 and 1.00 inch and apex depths of 0.030 to 0.100 inch
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	AA001(3)L; AA002(3)L; AA003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	166 Cracks / 499 opportunities. (Some defects / crack were lost during proof loading)
DETECTED:	-01(3)L = 184; -02(3)L = 146 ; -03(3)L = 236 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	166 flaws were induced in 93 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= Not Achieved A= Not Achieved A= Not Achieved
	Authors Note: The eddy current method is not applicable to this type of subsurface defect due to the variable nature of the defect location (depth) below the surface.
Test Specimen Descriptions	
on the following page!	

AA000(3)L	DATA SET DESCRIPTION - WELD LACK OF PENETRATATION (LOP) SPECIMENS
Material and Production Method:	2219 - T87 aluminum sheet and plate, welded by an automated gas tungsten arc (GTA) process from both sides of the plate to produce a lack of penetration (LOP-Lune) defect at the juncture of the two passes.
	The weld schedule was programmed to produce the LOP condition at the prescribed locations and sizes. The schedule for each defect class was validated by destructive test of several specimens prior to producing the test panels
	TEST SPECIMEN DESCRIPTORS



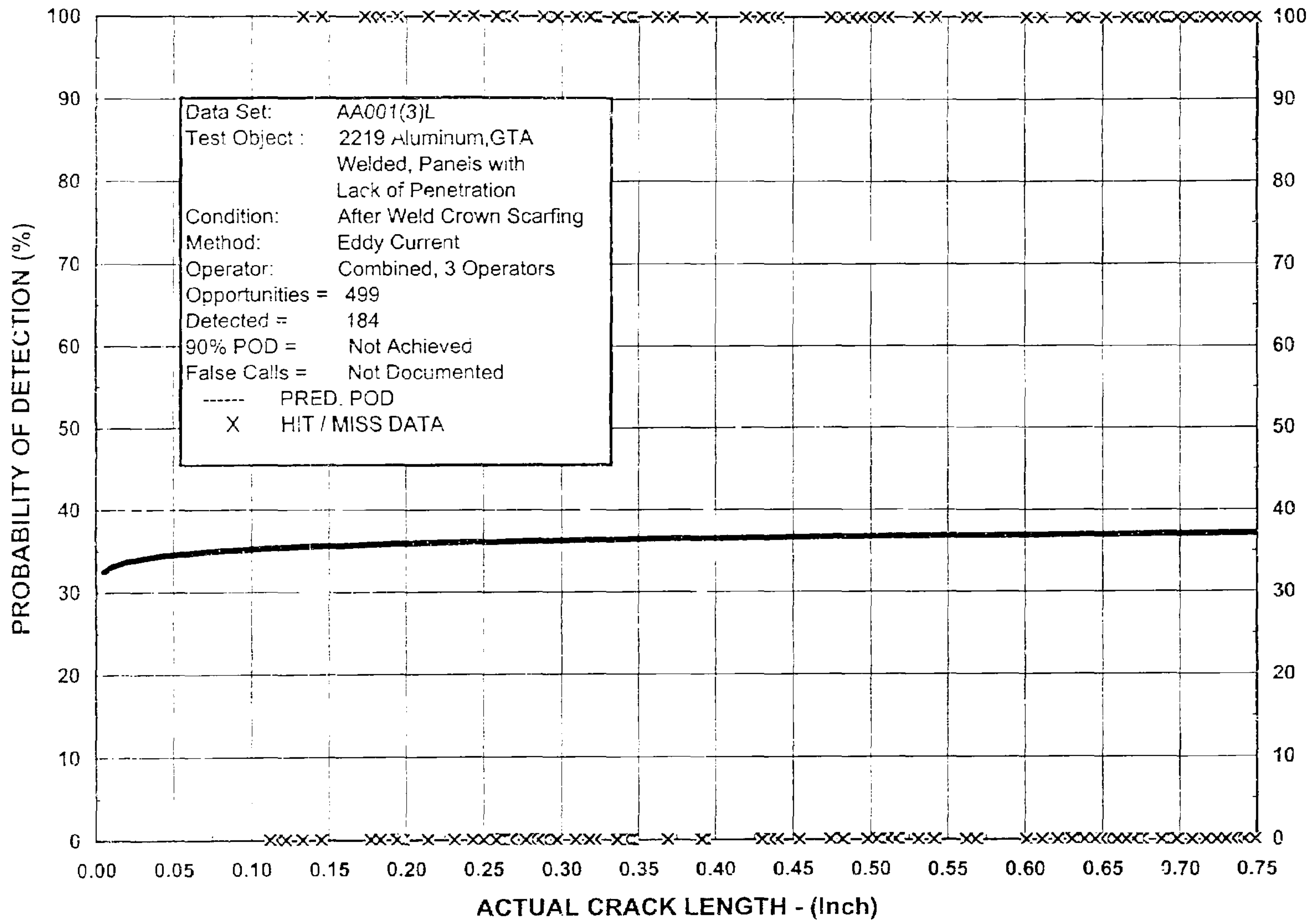
Schematic View of a Buried Lack of Penetration (LOP - Lune) *in a Weld, with Representative Photomicrograph Crossectional Views* of the Defect Configuration and Location.



Schematic Side View of a Lack of Penetration (LOP - Lune) Defect Showing the Location, Configuration and Critical Dimensions

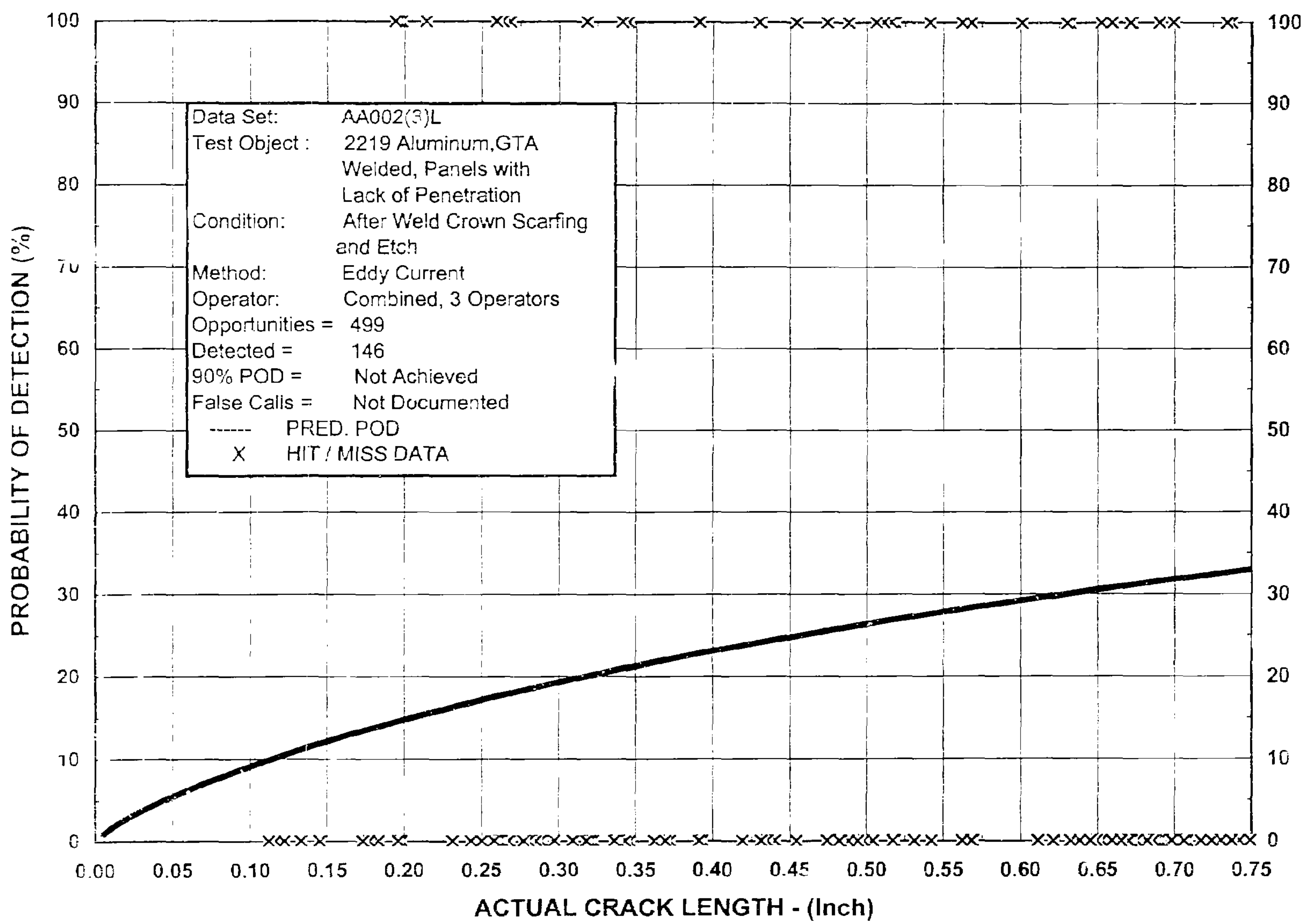
AA000(3)L

WELD LACK OF PENETRATION (LOP) TEST SPECIMENS



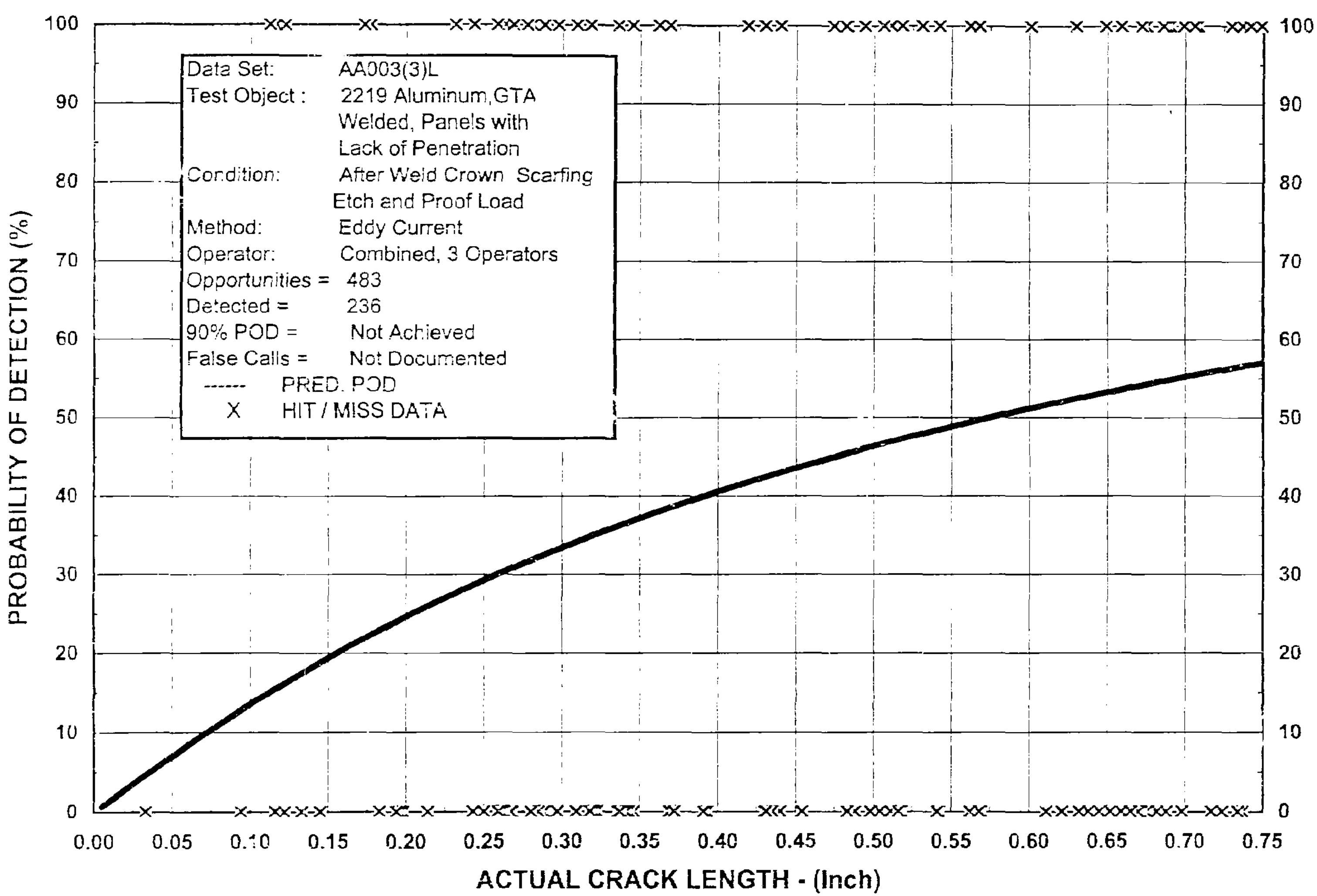
AA001(3)L
6/97 -AA001(3)L

Eddy Current Inspection - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing



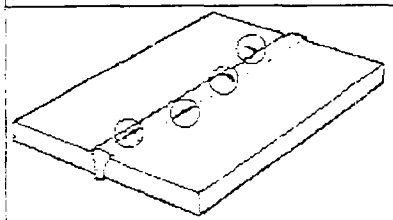
AA002(3)L
6/97 -AA002(3)L

Eddy Current Inspection - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etch



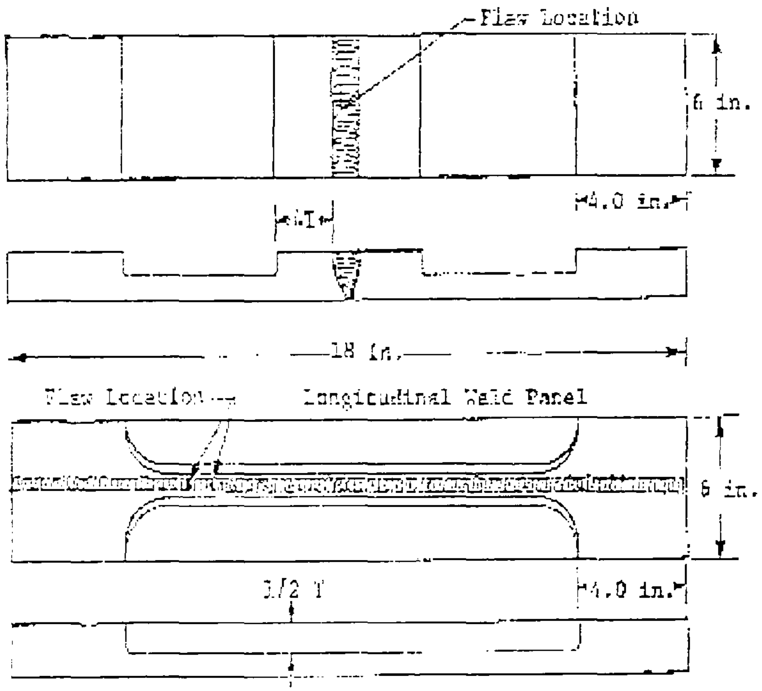
Eddy Current Inspection - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing, Etch and Proof Load

AA003(3)L
6/97 -AA003(3)L

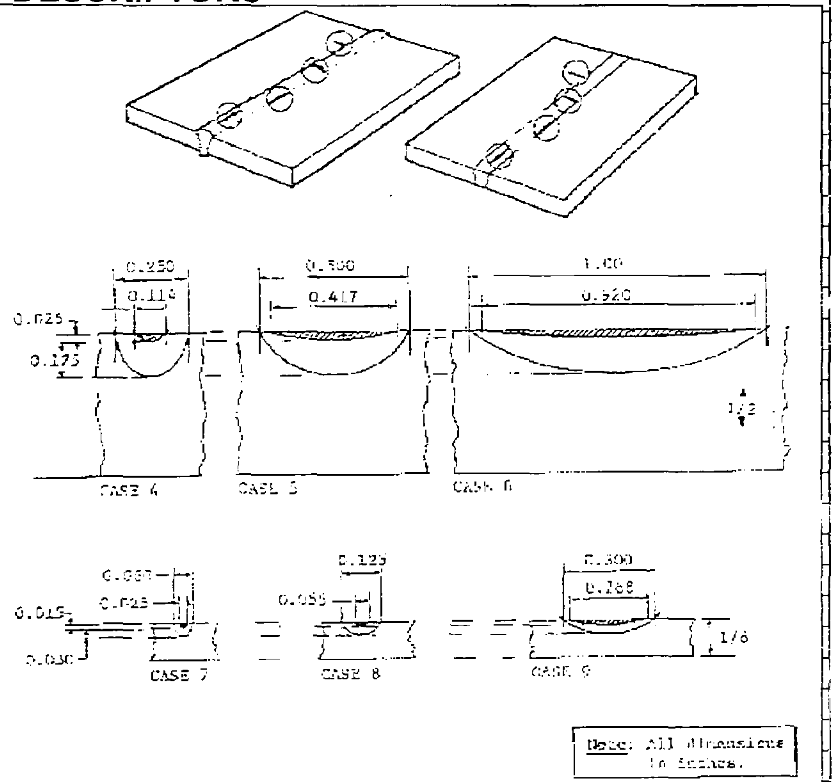
AB000(3)L	**DATA SET DESCRIPTION - LONGITUDINAL WELDS WITH CROWNS**
METHOD:	*Machine scan with a contact eddy current probe; threshold gating and recording.*
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	AB001(3)L: AB002(3)L: AB003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	162 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 71; -02(3)L = 50 ; -03(3)L = 59 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= Not Achieved A= Not Achieved A= Not Achieved
	Authors Note: Weld crowns varied in contour, thus resulting in variable lift off for the eddy current scans and poor detection results.
Test Specimen Descriptions	
on the following page!	
AB000(3)L	**DATA SET DESCRIPTION**

METHOD:	Machine scan with a contact eddy current probe; threshold gating and recording.
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in banding and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)

TEST SPECIMEN DESCRIPTORS



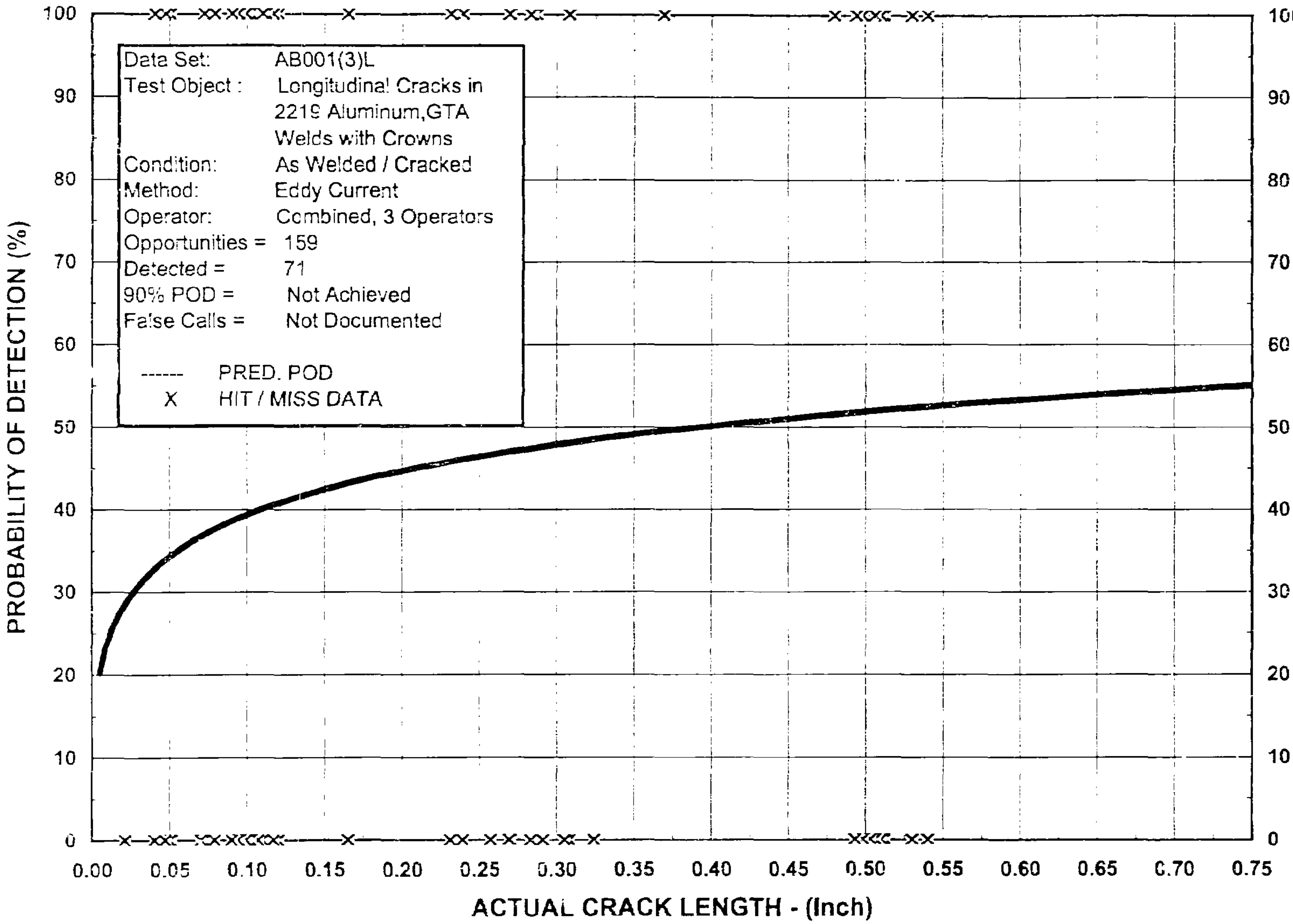
WELD PANEL CONFIGURATION



CRACK LOCATION AND ORIENTATION

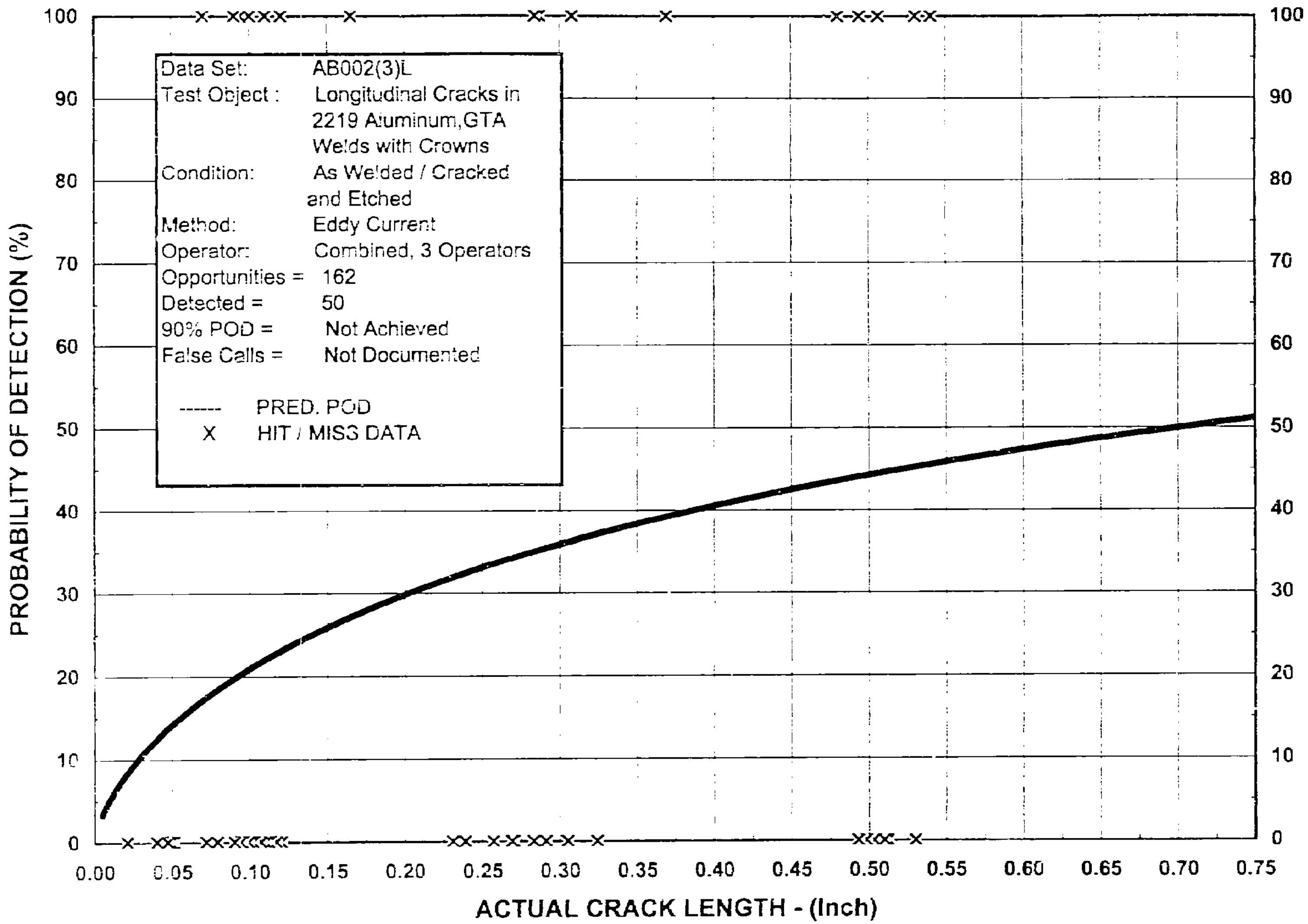
EDDY CURRENT INSPECTION
INDUCED FATIGUE CRACKS IN WELD PANELS

AB000(3)L



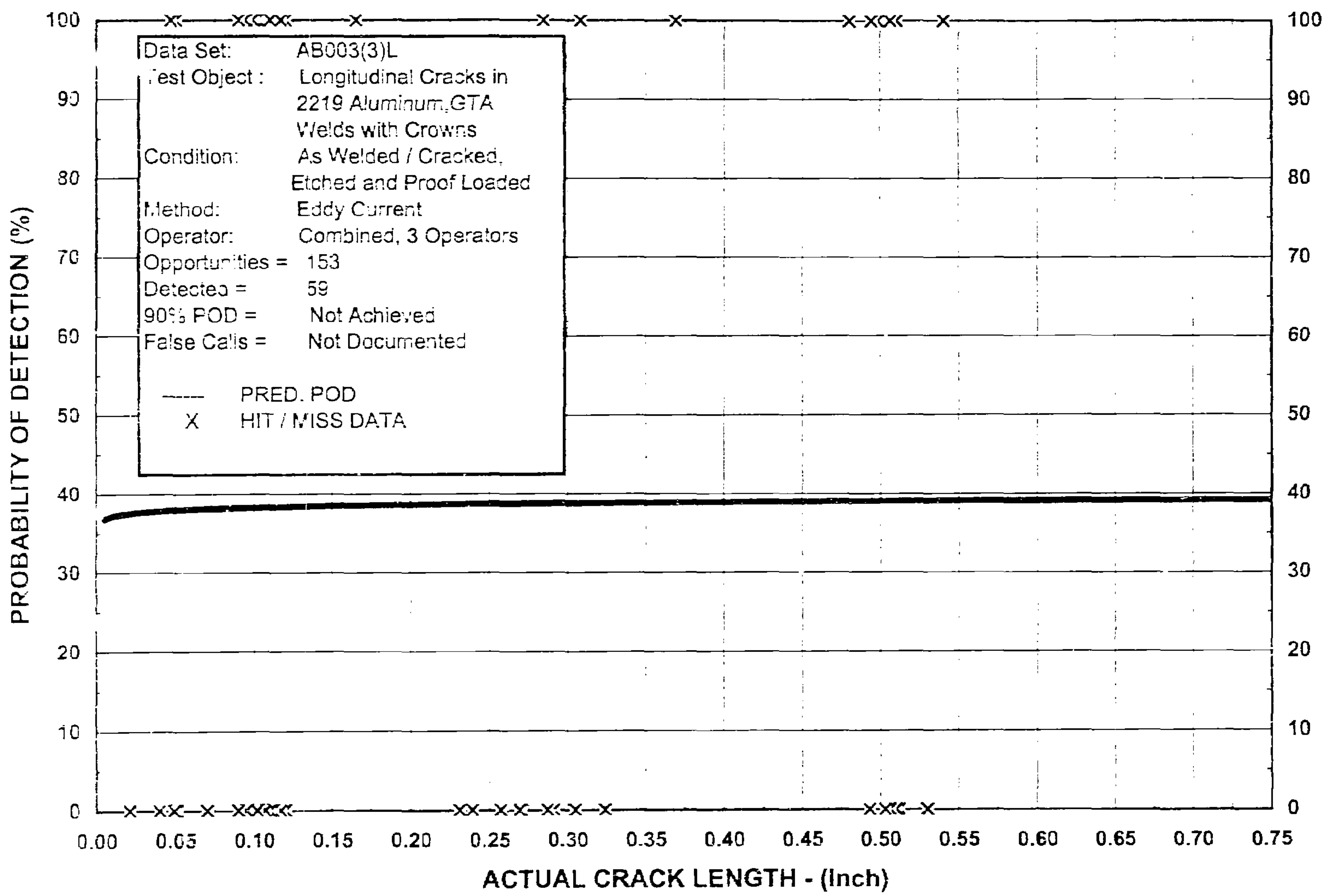
AB001(3)L
6/97 -AB001(3)L

Eddy Current - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



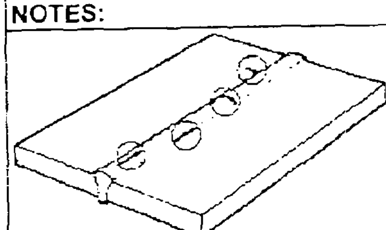
AB002(3)L
6/97 -AB002(3)L

Eddy Current - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched

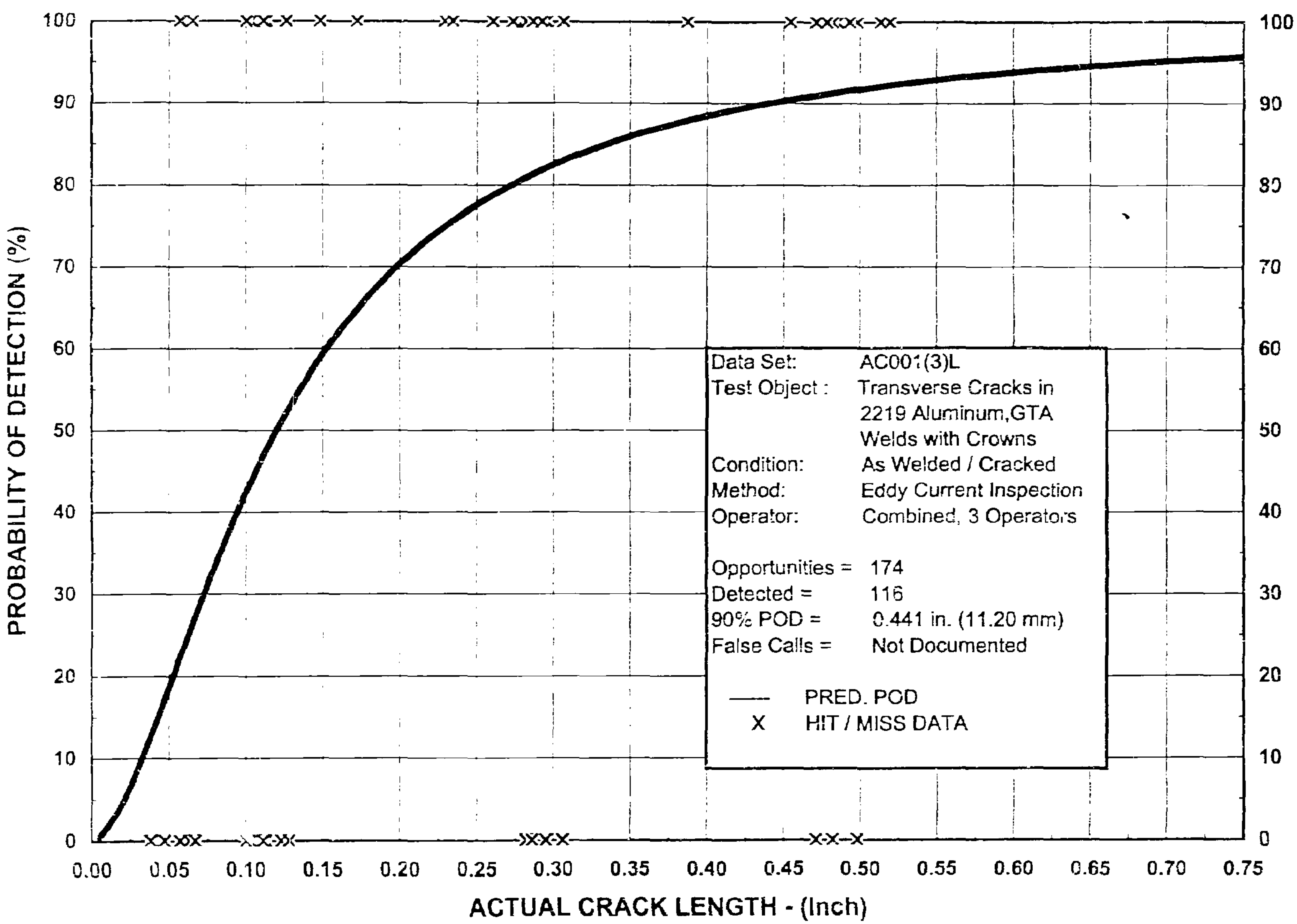


AB003(3)L
6/97 -AB003(3)L

Eddy Current - 3 Operators Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds
As Cracked, Scarfed, Etched and Proof Loaded

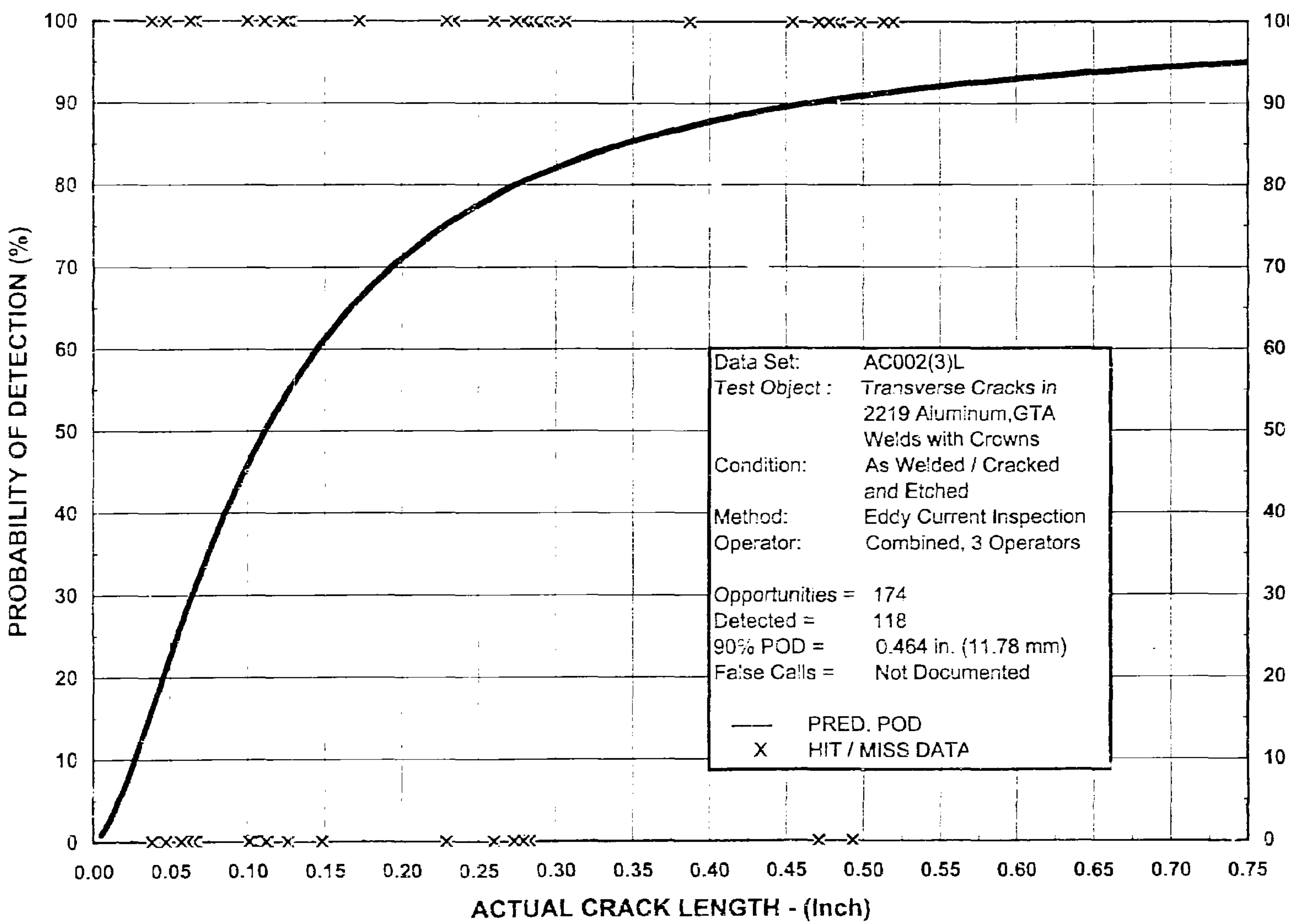
AC000(3)L	**DATA SET DESCRIPTION - TRANSVERSE CRACKS IN WELDS WITH CROWNS**
METHOD:	Machine scan with a contact eddy current probe; threshold gating and recording.
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. *Fusion and filler pass from one side.*
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< C. 70 (Shaped EDM notch initiation, *in bending and tension / tension)*
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02 "After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	AC001(3)L; AC002(3)L; AC003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	174 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 116; -02(3)L = 118 ; -03(3)L = 110 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD)
	239 *cracks* (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= 0.441 in. (11.20 mm) A= 0.464 in. (11.78 mm) A= 0.746 in. (18.94 mm)
	Authors Note: Weld crowns varied in contour, thus resulting in variable lift off for the eddy current scans and *poor detection results. Decrease in detection after proof loading is attributed to the change in crack profile* within the probe field.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	

EDDY CURRENT INSPECTION
INDUCED FATIGUE CRACKS IN WELD PANELS



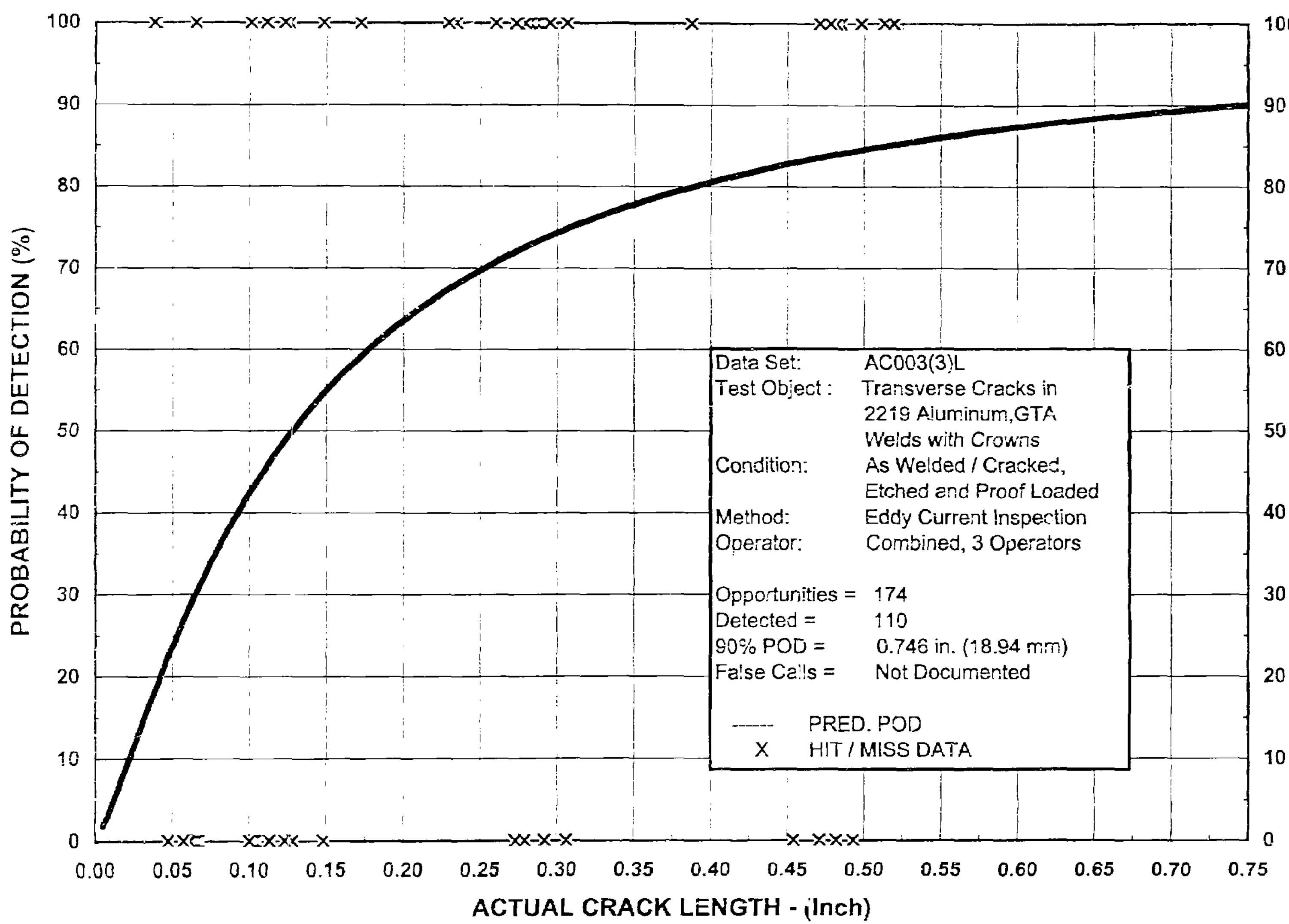
AC001(3)L
6/97 -AC001(3)L

Eddy Current Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



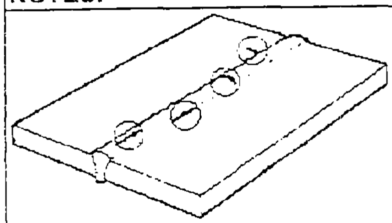
AC002(3)L
6/97 -AC002(3)L

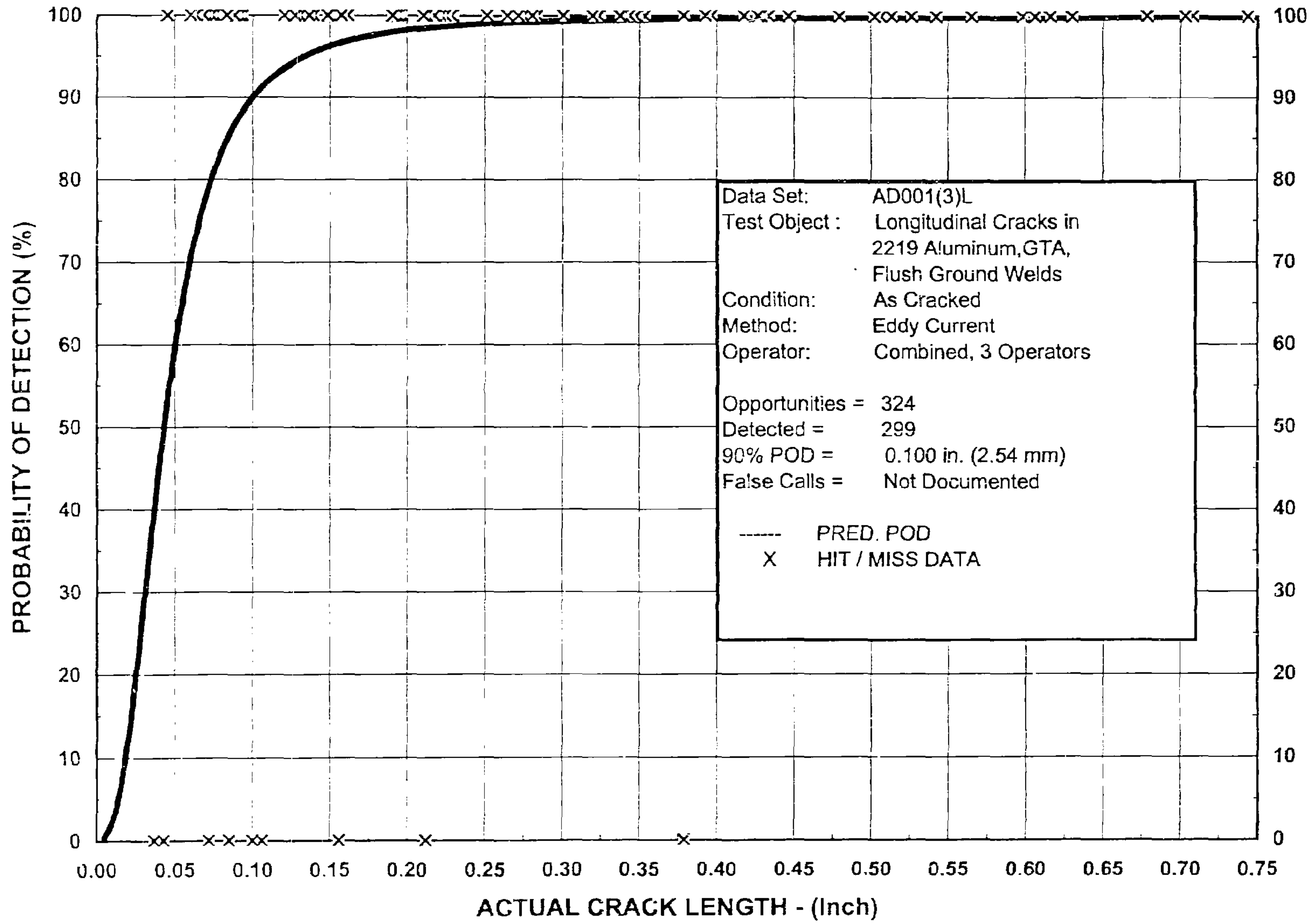
Eddy Current Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched



AC003(3)L
6/97 -AC003(3)L

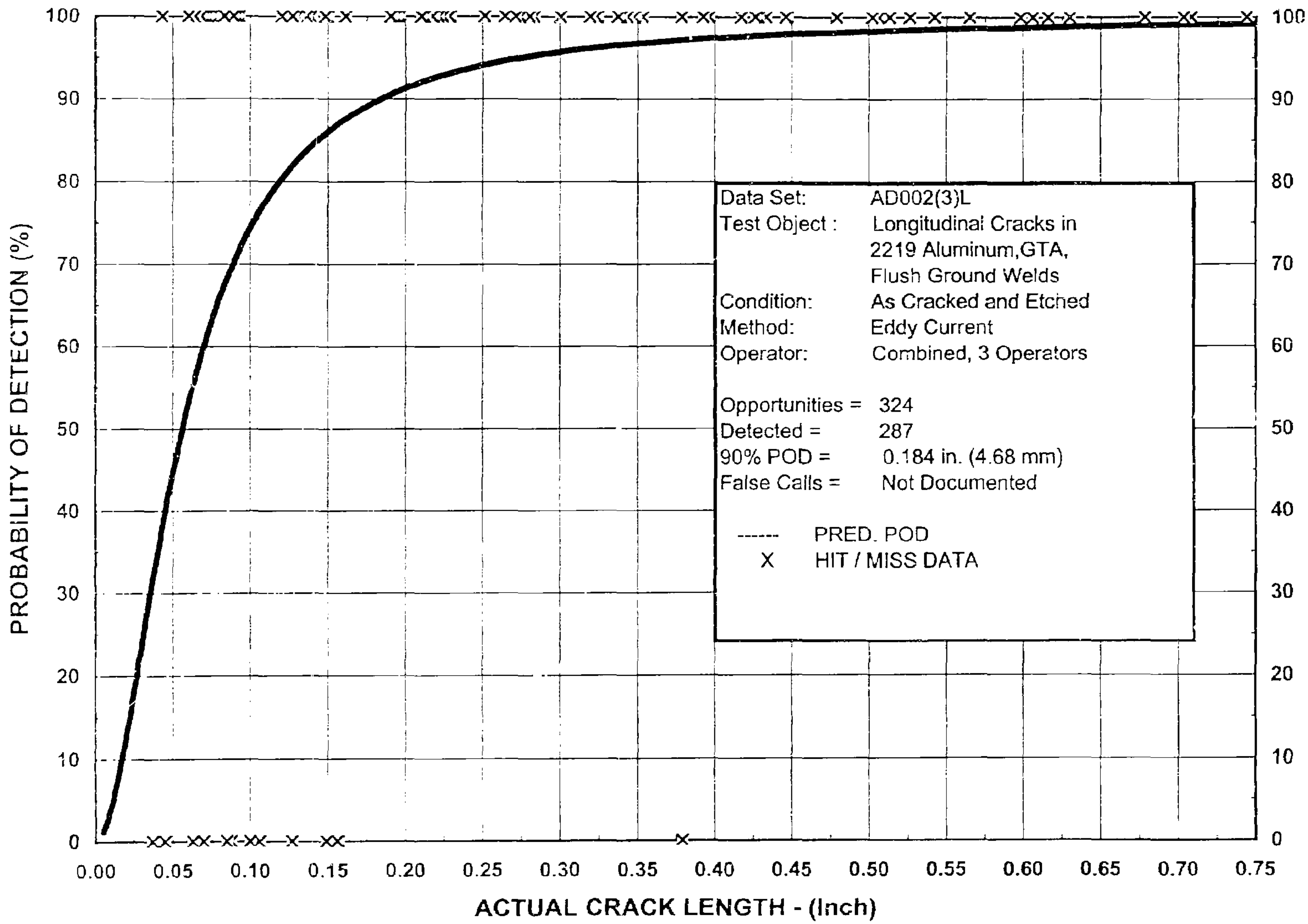
Eddy Current Inspection- 3 Operators Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed, Etched and Proof Loaded

AD000(3)L	DATA SET DESCRIPTION - LONGITUDINAL CRACKS IN FLUSH WELDS
METHOD:	Machine scan with a contact eddy current probe; threshold gating and recording.
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	AD001(3)L; AD002(3)L; AD003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	324 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 299; -02(3)L = 287 ; -03(3)L = 279 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= 0.100 in. (2.54 mm) A= 0.187 in. (4.68 mm) A= 0.109 in. (2.77 mm)
	Authors Note: Weld crowns varied in contour, thus resulting in variable lift off for the eddy current scans and poor detection results. Decrease in detection *after proof loading is attributed to the change in crack profile* within the probe field.
Test Specimen Descriptions	
in AB000(3)L, Page 2	



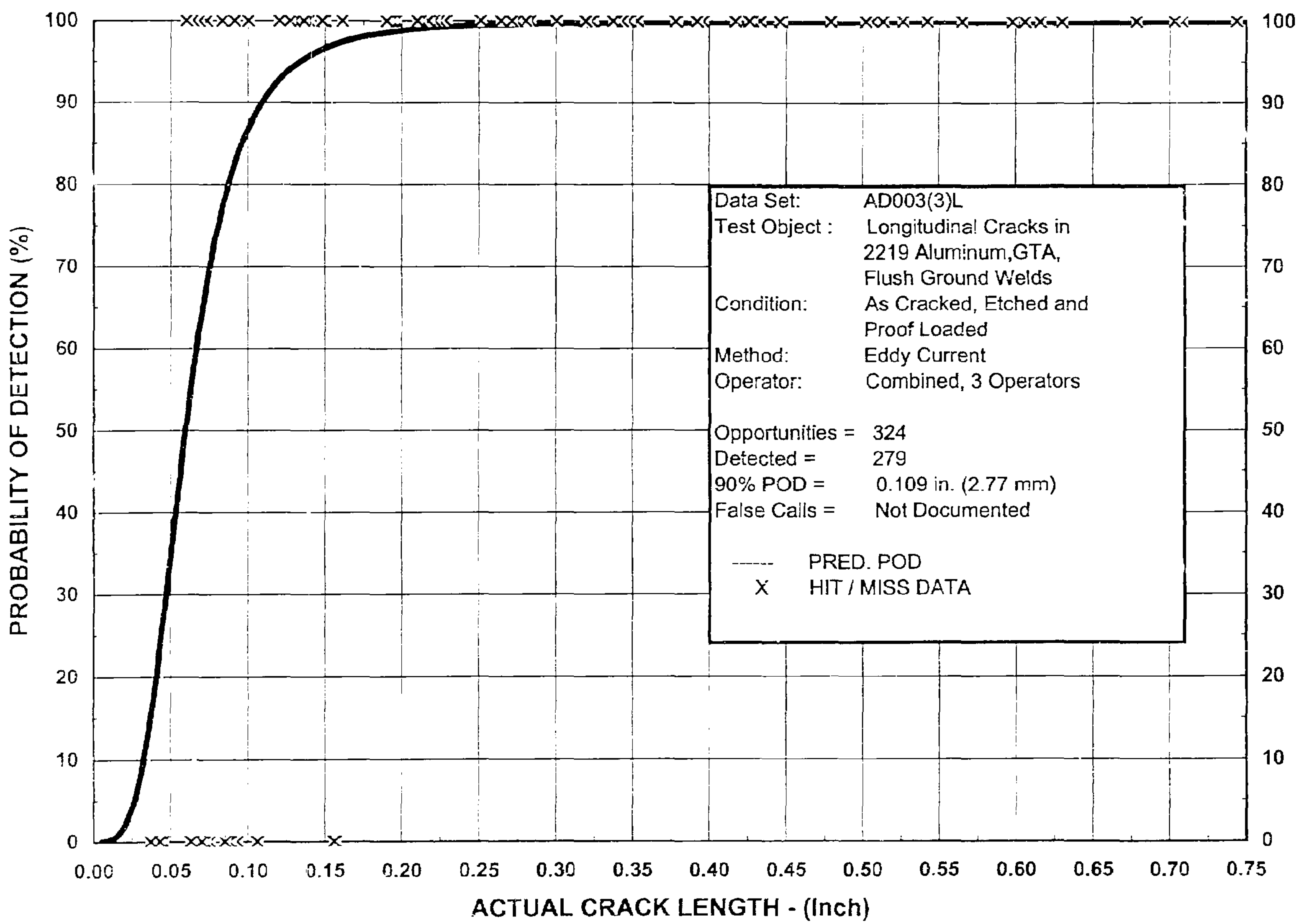
AD001(3)L
6/97 - AD001(3)L

Eddy Current Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



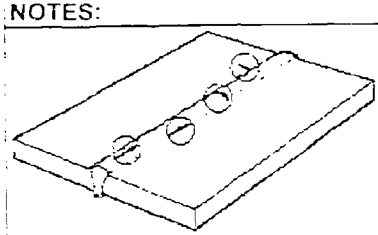
AD002(3)L
6/97 - AD002(3)L

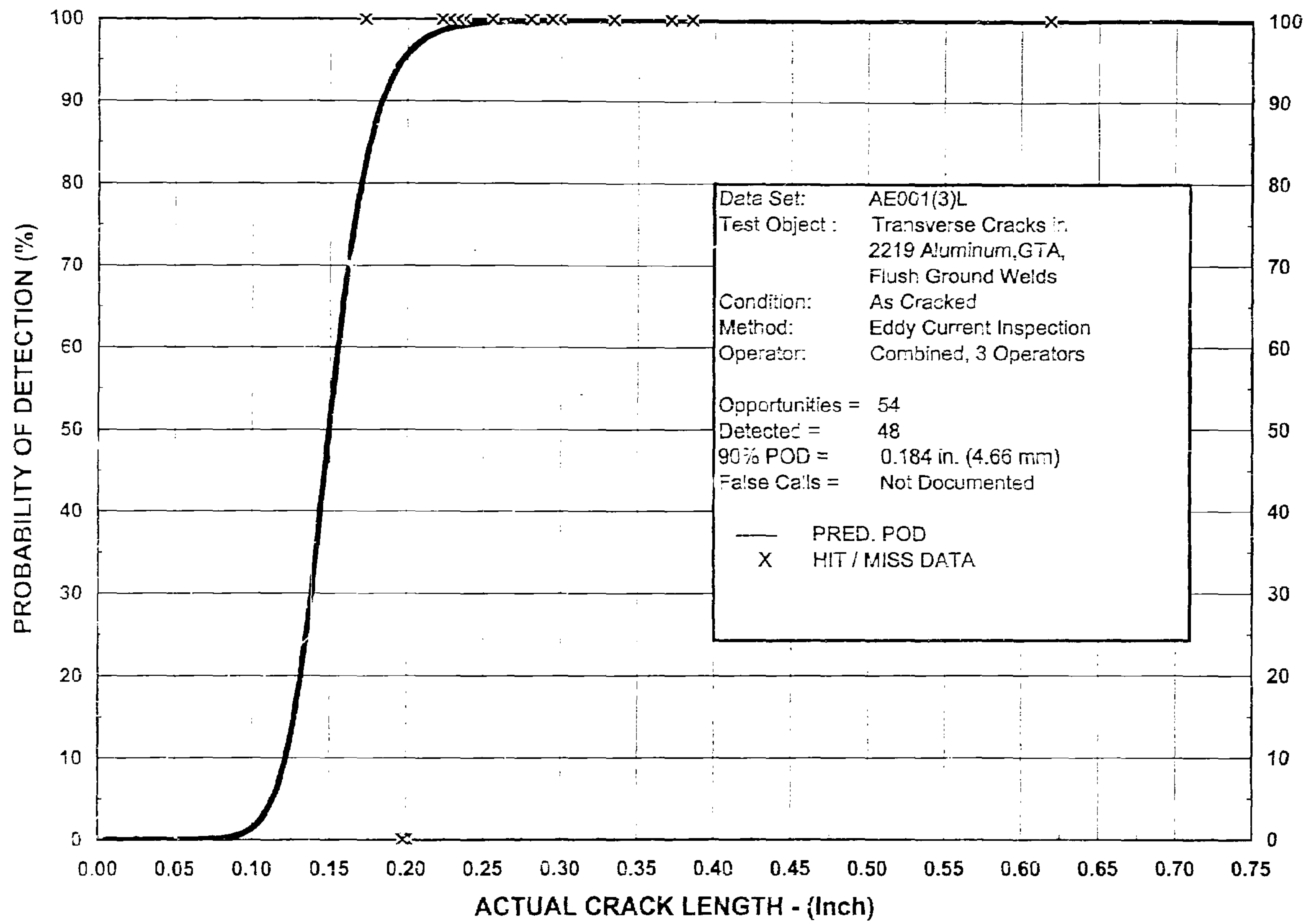
Eddy Current Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching



AD003(3)L
6/97 - AD003(3)L

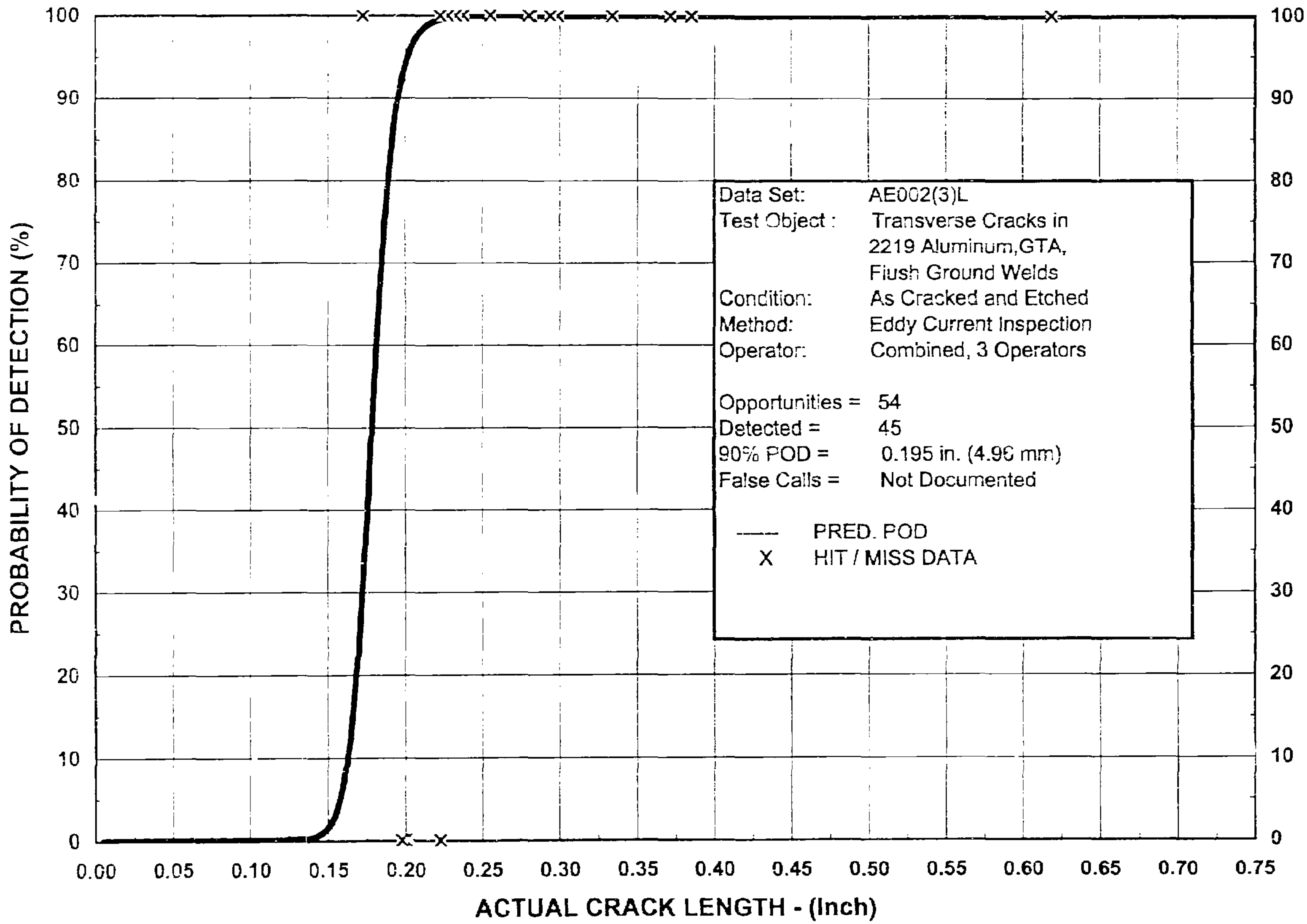
Eddy Current Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Load

AE000(3)L	**DATA SET DESCRIPTION - TRANSVERSE CRACKS IN FLUSH WELDS**
METHOD:	Machine scan with a contact eddy current probe; threshold gating and recording.
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Alumirum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	AE001(3)L; AE002(3)L; AE003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	54 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 48; -02(3)L = 45 ; -03(3)L = 54 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **<u>The Detection of Tightly Closed Flaws by Nondestructive Testing Methods</u>**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% or the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= 0.184 in. (4.66 mm) A= 0.195 in. (4.96 mm) A= No Test
	Authors Note: This data set was too small to provide for good discrimination.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	



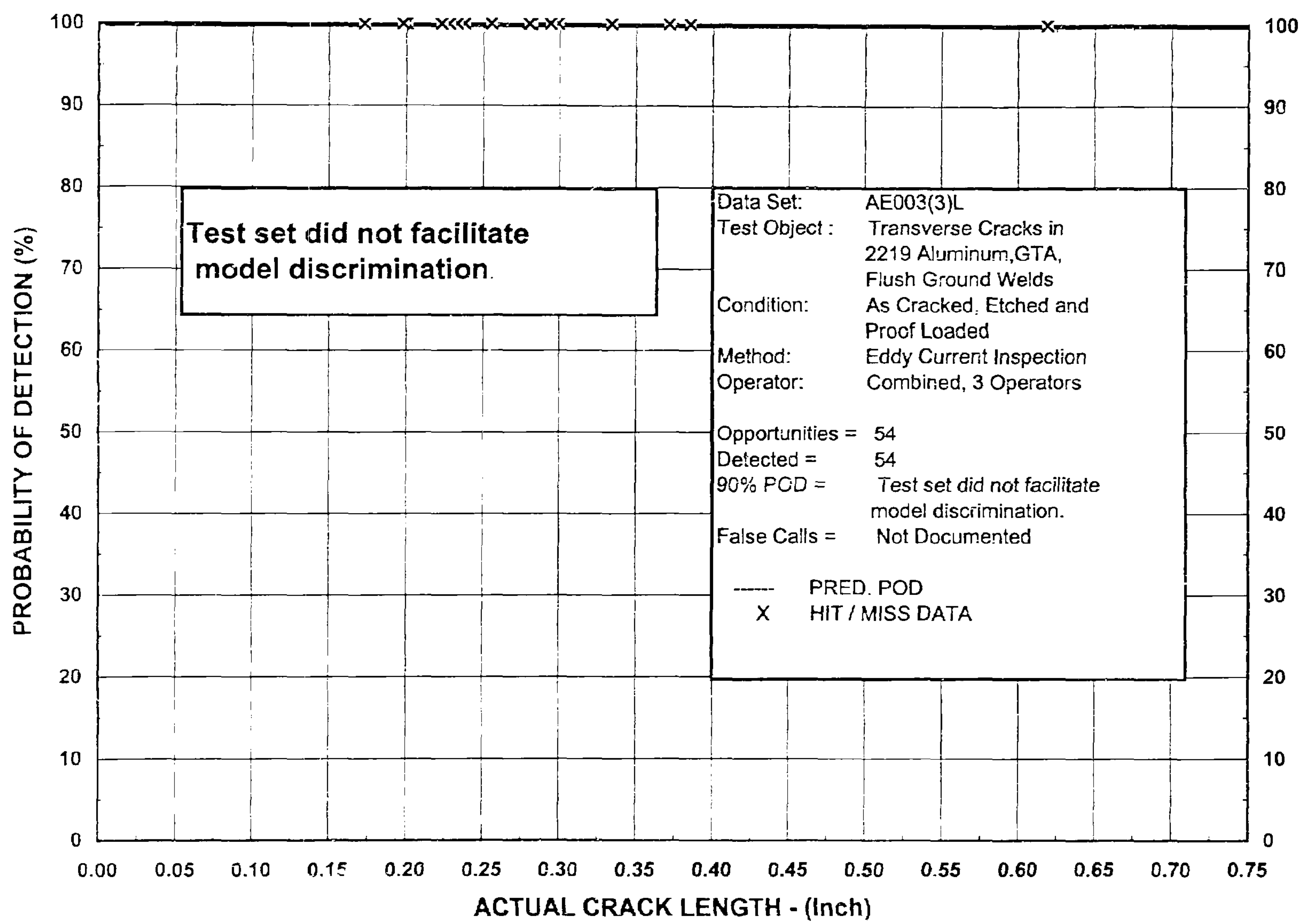
AE001(3)L
8/97 -AE001(3)L

Eddy Current Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



AE002(3)L
8/97 -AE002(3)L

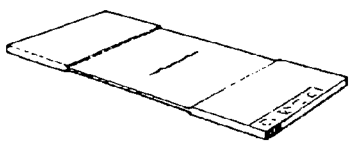
Eddy Current Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching



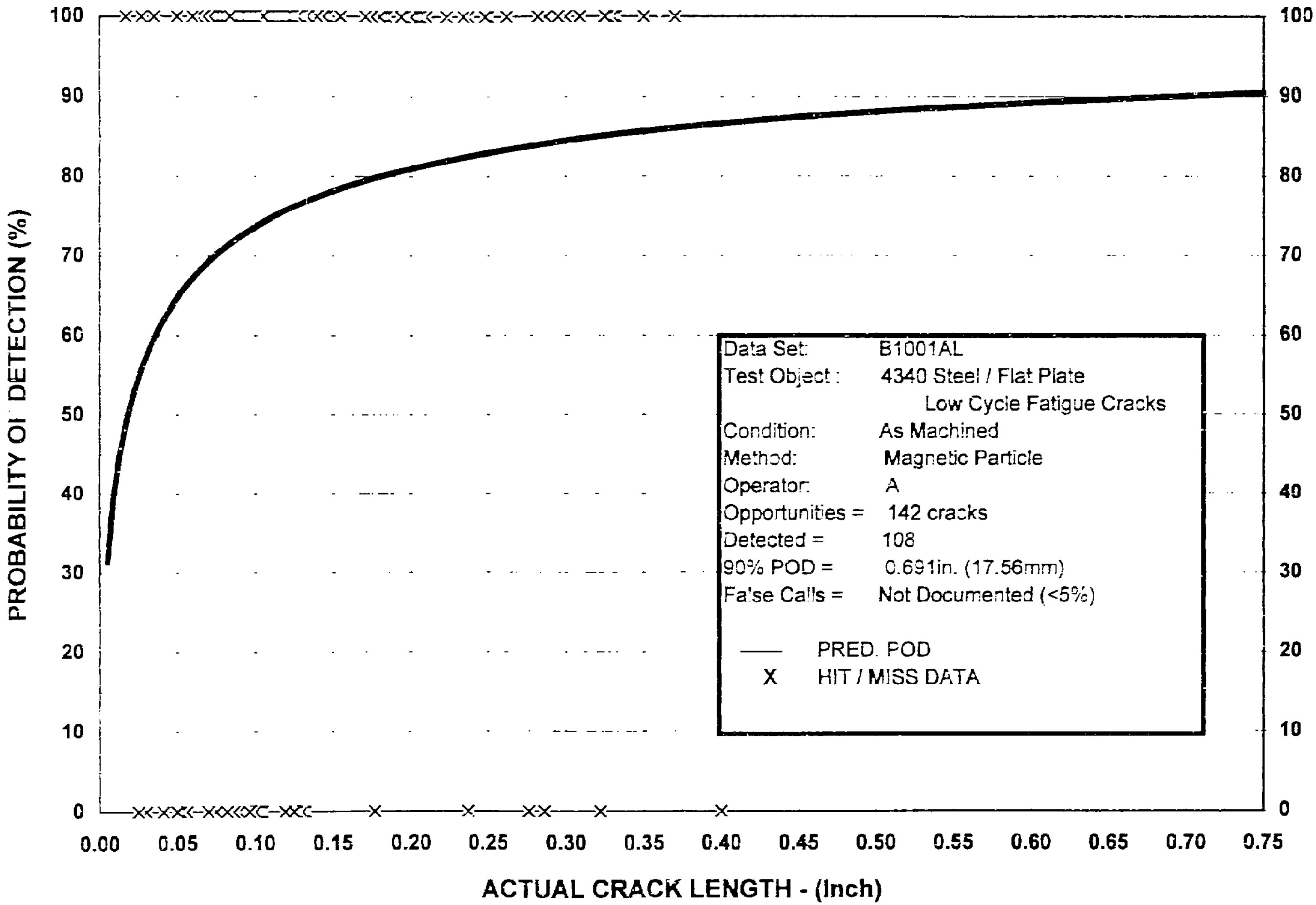
AE003(3)L
8/97 -AE003(3)L

Eddy Current Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading

B1000(2)L	DATA SET DESCRIPTION
METHOD:	Magnetic Particle Inspection by CRACK LENGTH
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Fluorescent magnetic particle in a wet horizontal machine
ARTIFACT TYPE:	Fatigue Cracks - R< 0.70 (Shaped EDM starter notch initiation, growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	B1001,"As Machined"; B1003,"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Processing / Manual Inspection (Wet Horizontal / Uresco 228 fluorescent particles)
DATA SET IDENTIFIER:	B1001-A,B,C; B1003-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	176 Cracks -Variation in the number inspected during each sequence
DETECTED:	B1001 - A = 108/142, B= 120/142, C= 120/142; B1003 - A= 124/176, B= 142/176, C= 154/176
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen. **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



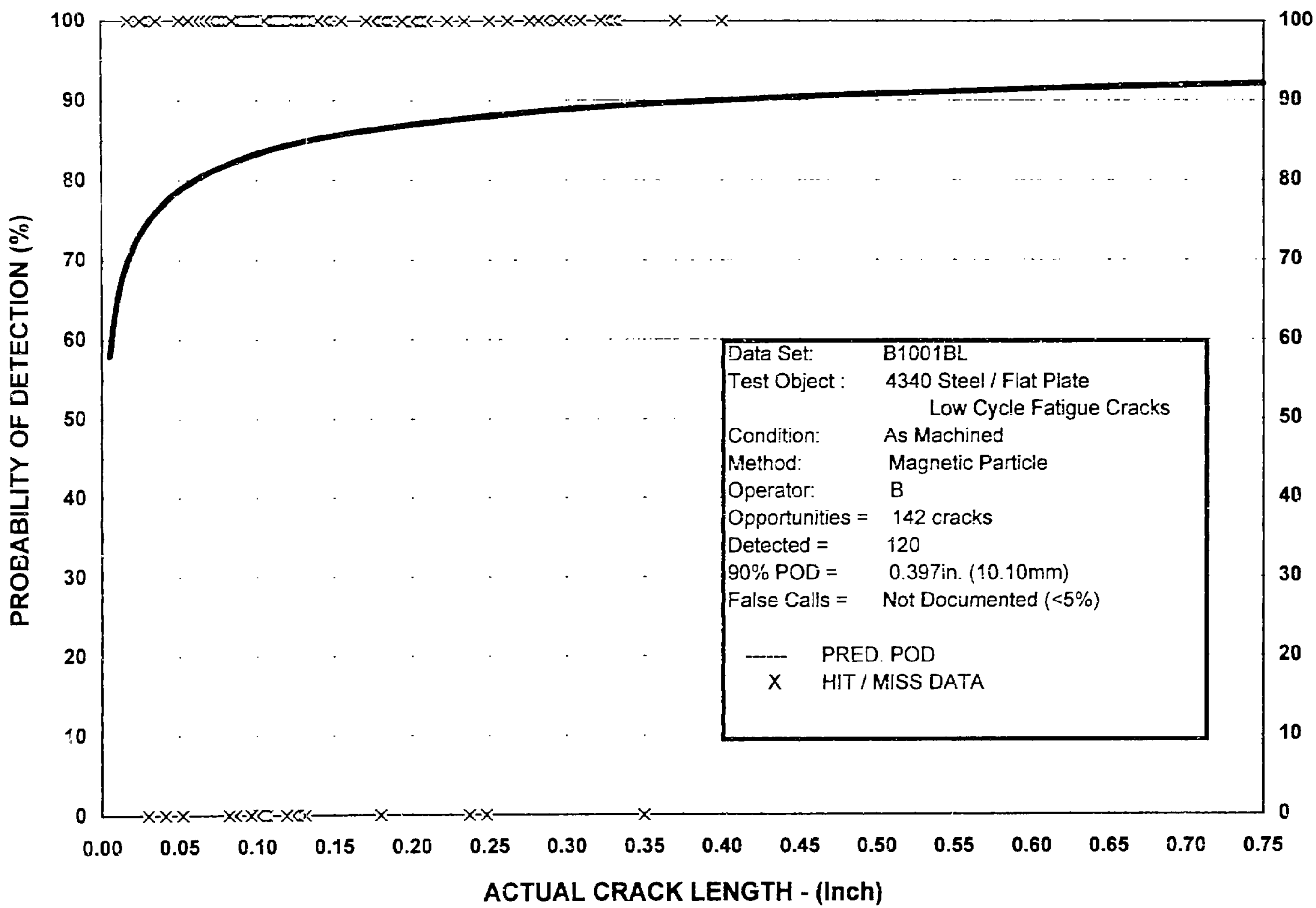
CRACK LENGTH		
90% POD	"AS MACHINED"	"AFTER PROOF"
	A= 0.691in. (17.56mm)	A= 0.259in. (6.59mm)
	B= 0.397in. (10.10mm)	B= 0.106in. (2.68mm)
	C= 0.366in. (9.31mm)	C= 0.120in. (3.04mm)



B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS

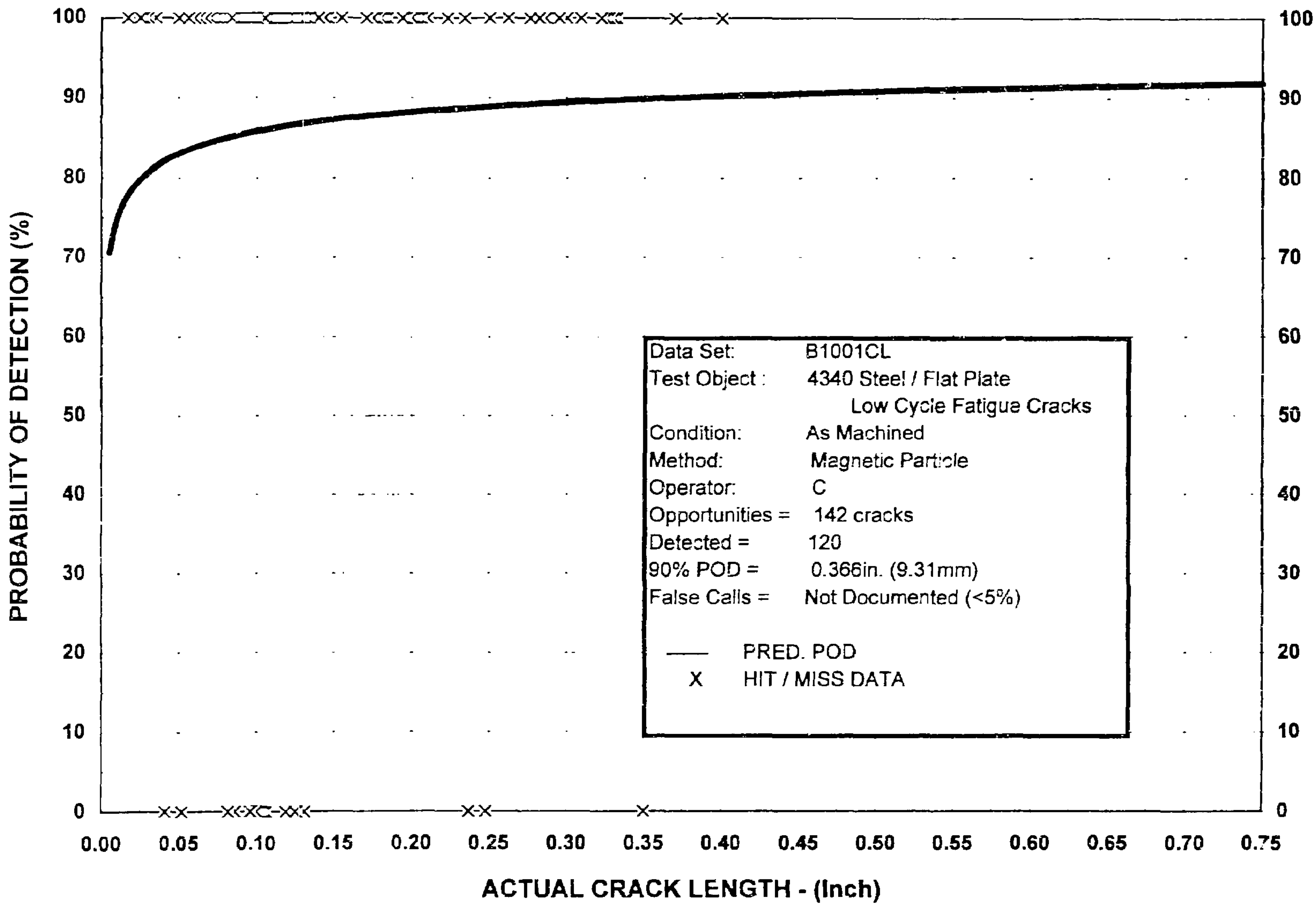
9/96 - B7001AL

B1001AL
AS MACHINED - OPERATOR A



B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS
9/96 - B1001BL

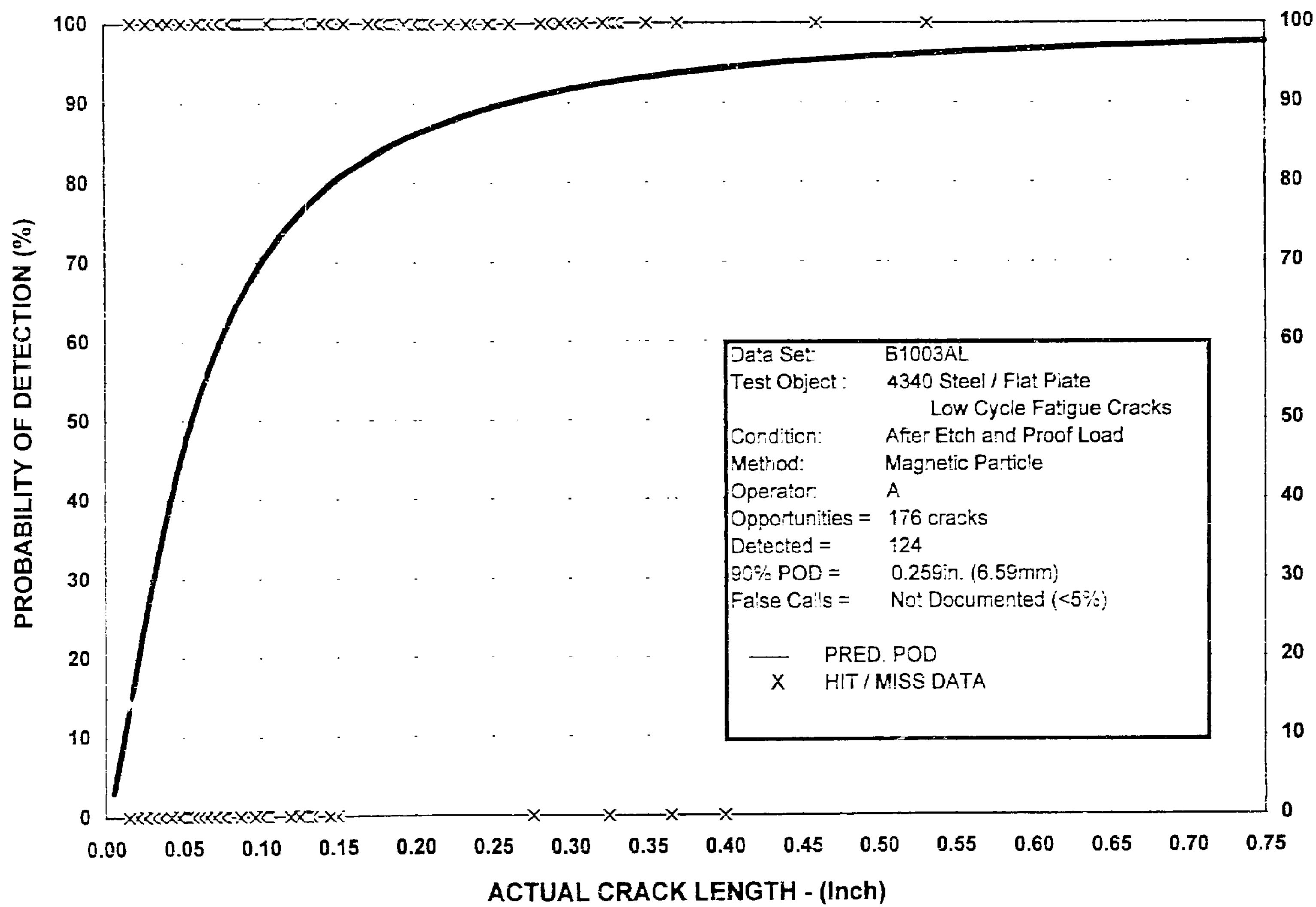
B1001BL
AS MACHINED - OPERATOR B



B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS

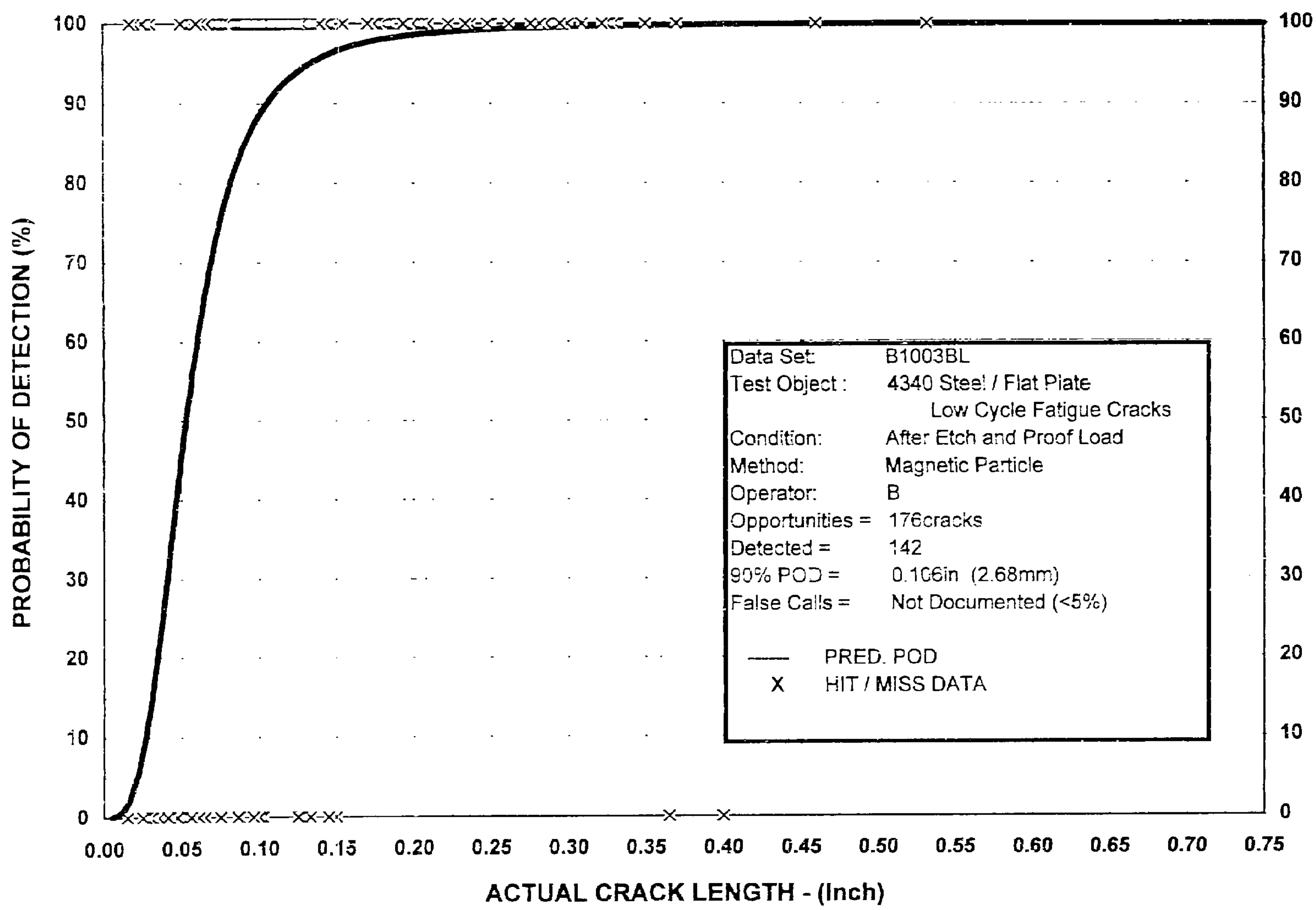
9/96 - B1001CL

B1001CL
AS MACHINED - OPERATOR C



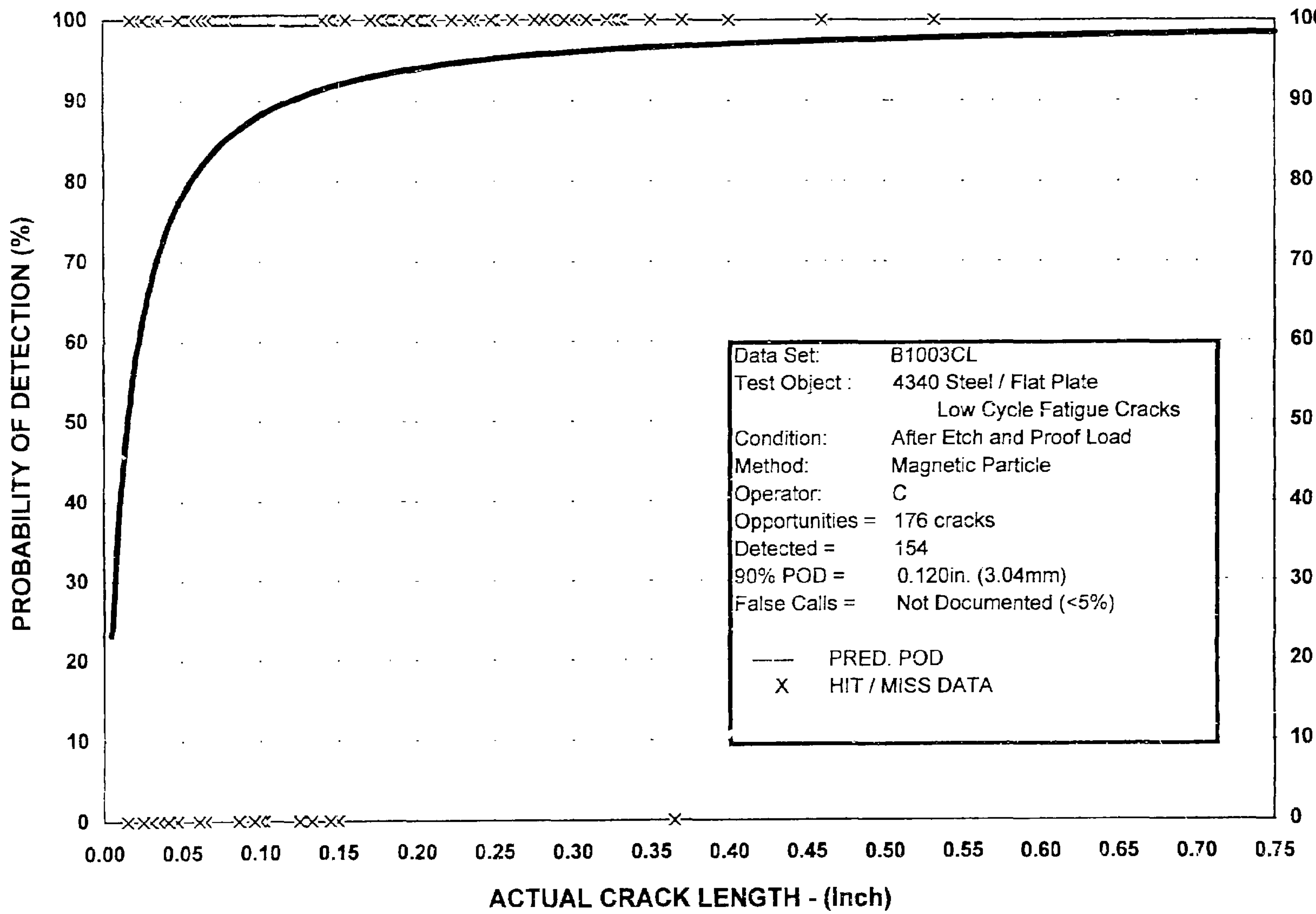
B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS
9/96 - B1003AL

B1003AL
AFTER ETCH AND PROOF LOAD
OPERATOR A



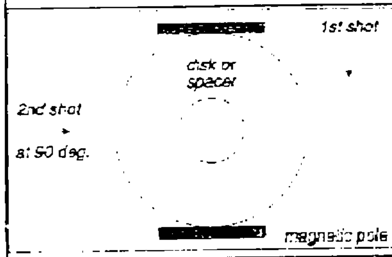
B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS
9/96 - B1003BL

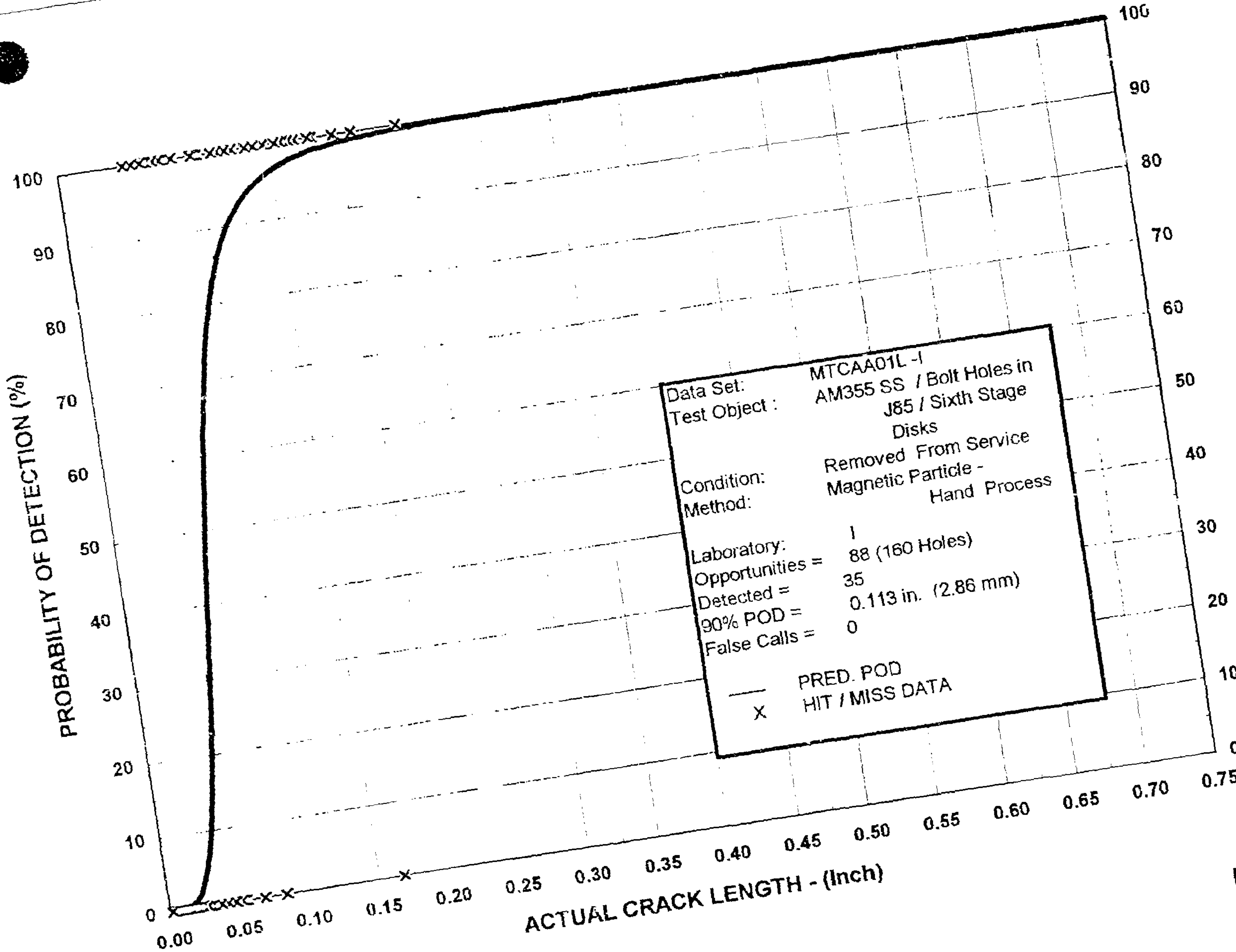
B1003BL
AFTER ETCH AND PROOF LOAD
OPERATOR B



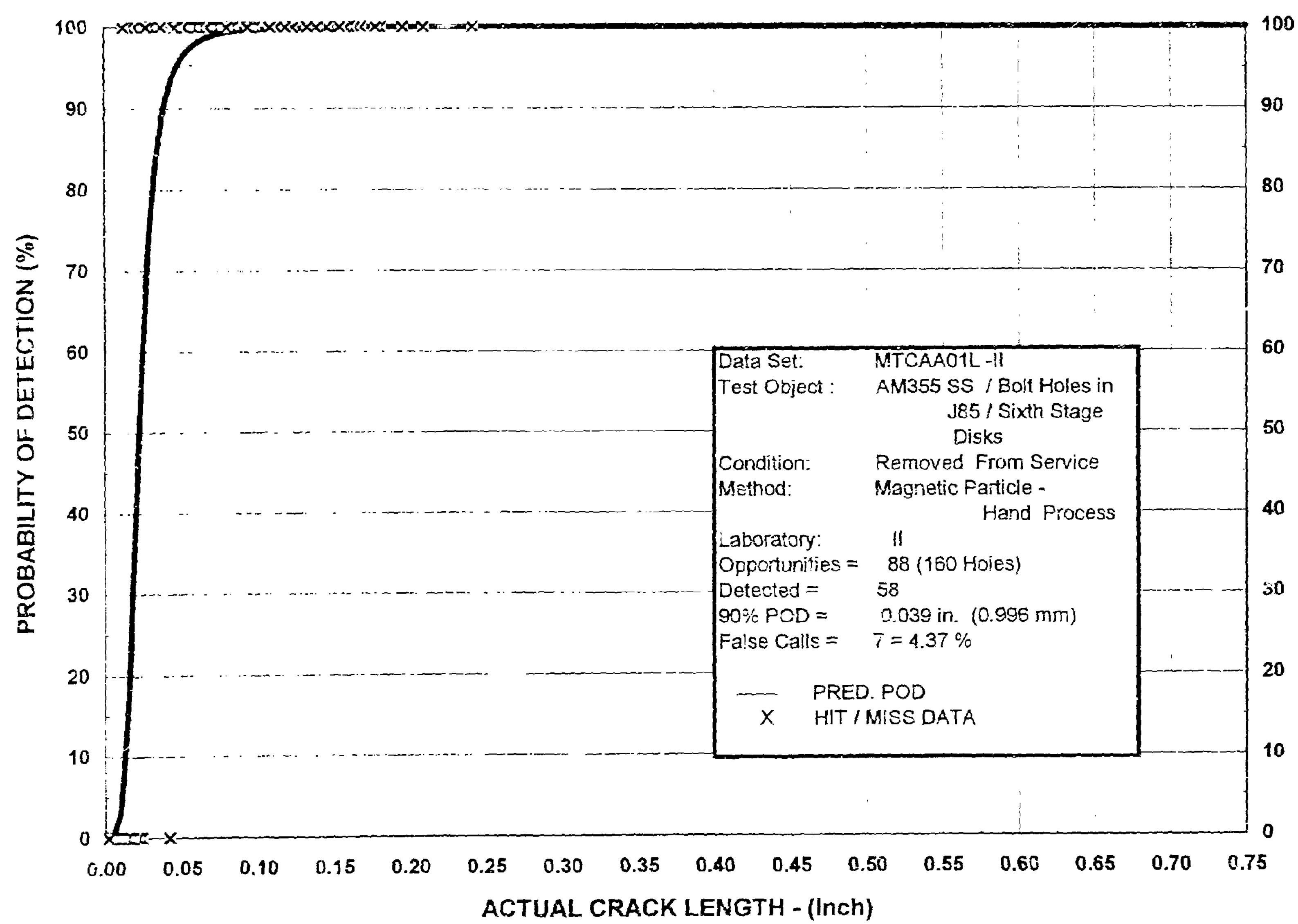
B1000(2) MAGNETIC PARTICLE INSPECTION
OF 4340 STEEL PANELS
9/96 - B1003CL

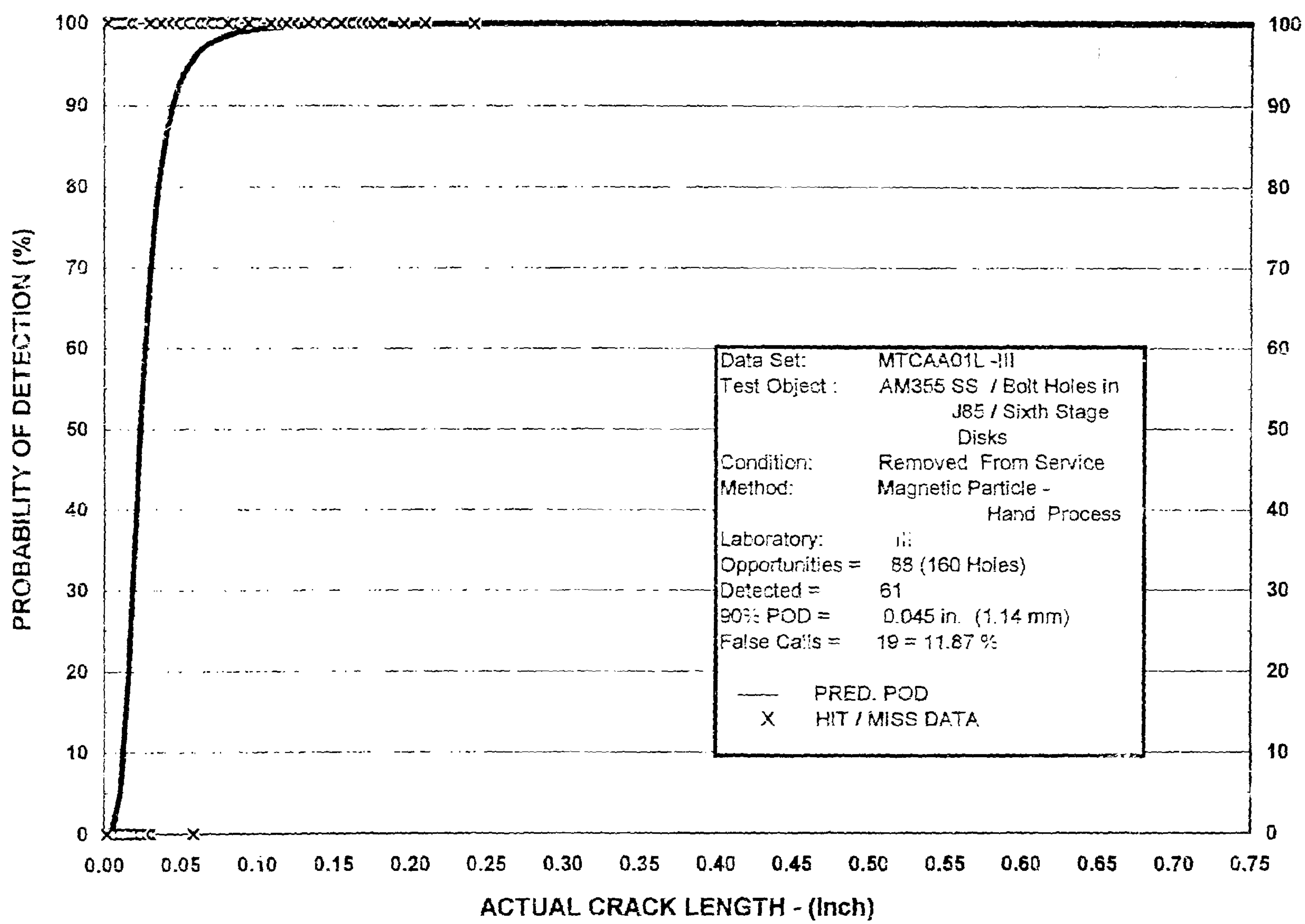
B1003CL
AFTER ETCH AND PROOF LOAD
OPERATOR C

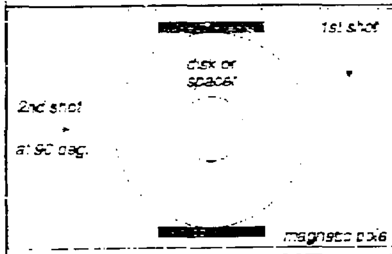
MT-02(4)	DATA SET DESCRIPTION
METHOD:	Magnetic Particle
TEST OBJECT TYPE:	Bolt holes in J85 / sixth stage compressor disks; 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Magnetic partical per MIL STD 1949A
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	MTCAA01L -I ; MTCAA01L-II; and MTCAA01L-III
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	160 holes with 88 cracks
DETECTED:	ORG I: 35; ORG II: 58; ORG III: 61
FALSE CALLS:	ORG I: 0; ORG II: 7 = 4.37% ORG III: 19 = 11.7 %
REFERENCE:	LTR-ST-1961 Fahr. A., D. Forsyth. M. Bullock and W. Wallace, <u>**NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**</u>, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO. Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research. National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD - ORG I: 0.113 in. (2.86 mm) ORG II: 0.039 in. (0.996 mm) ORG III: 0.045 in. (1.14 mm)

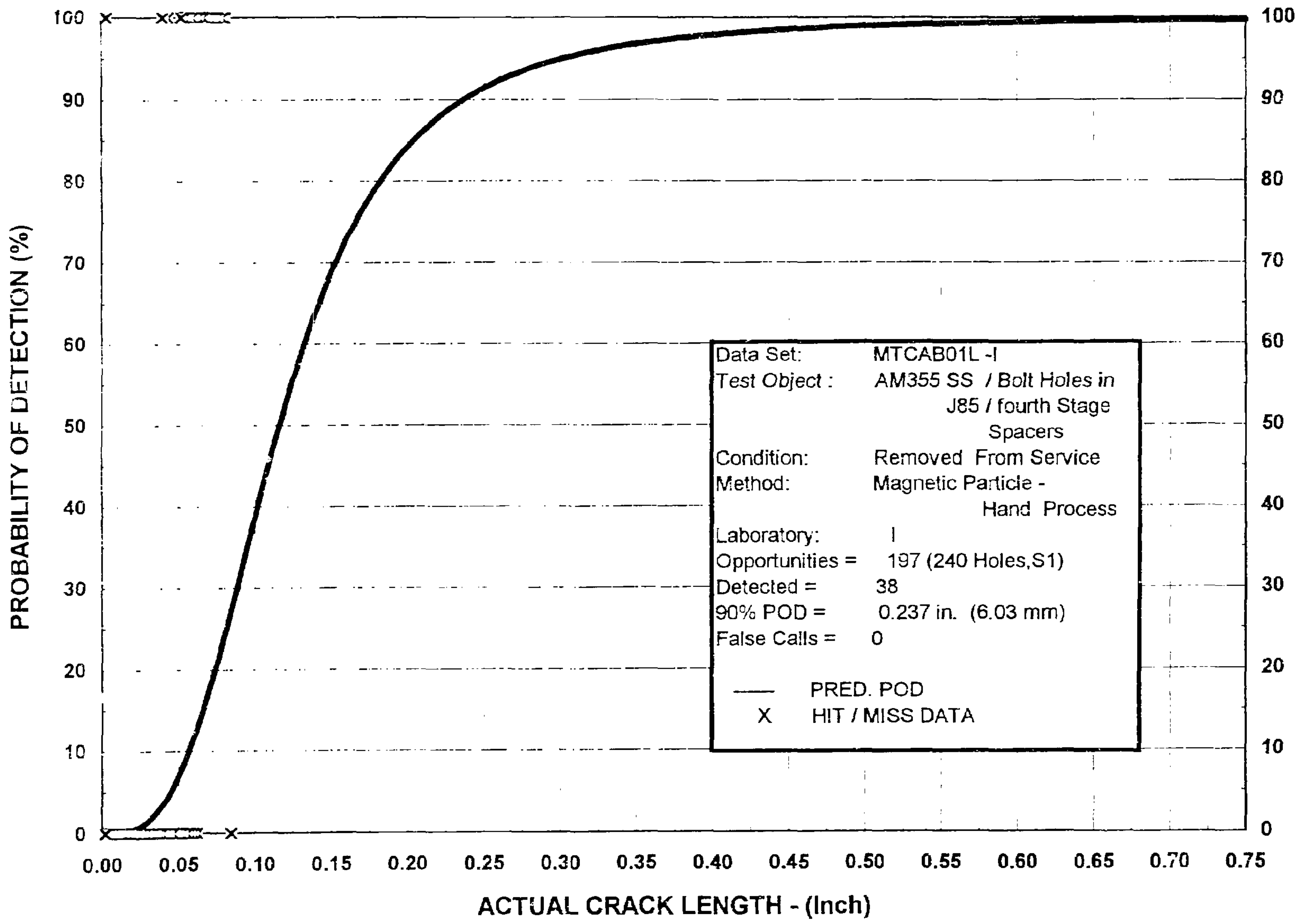


MTCAA01L-I
(ORG. I)


Data Set: MTCAA01L -II
Test Object : AM355 SS / Bolt Holes in J85 / Sixth Stage Disks
Condition: Removed From Service
Method: Magnetic Particle - Hand Process
Laboratory: II
Opportunities = 88 (160 Holes)
Detected = 58
90% POD = 0.039 in. (0.996 mm)
False Calls = 7 = 4.37 %
PRED. POD
X HIT / MISS DATA
PROBABILITY OF DETECTION (%)
ACTUAL CRACK LENGTH - (Inch)

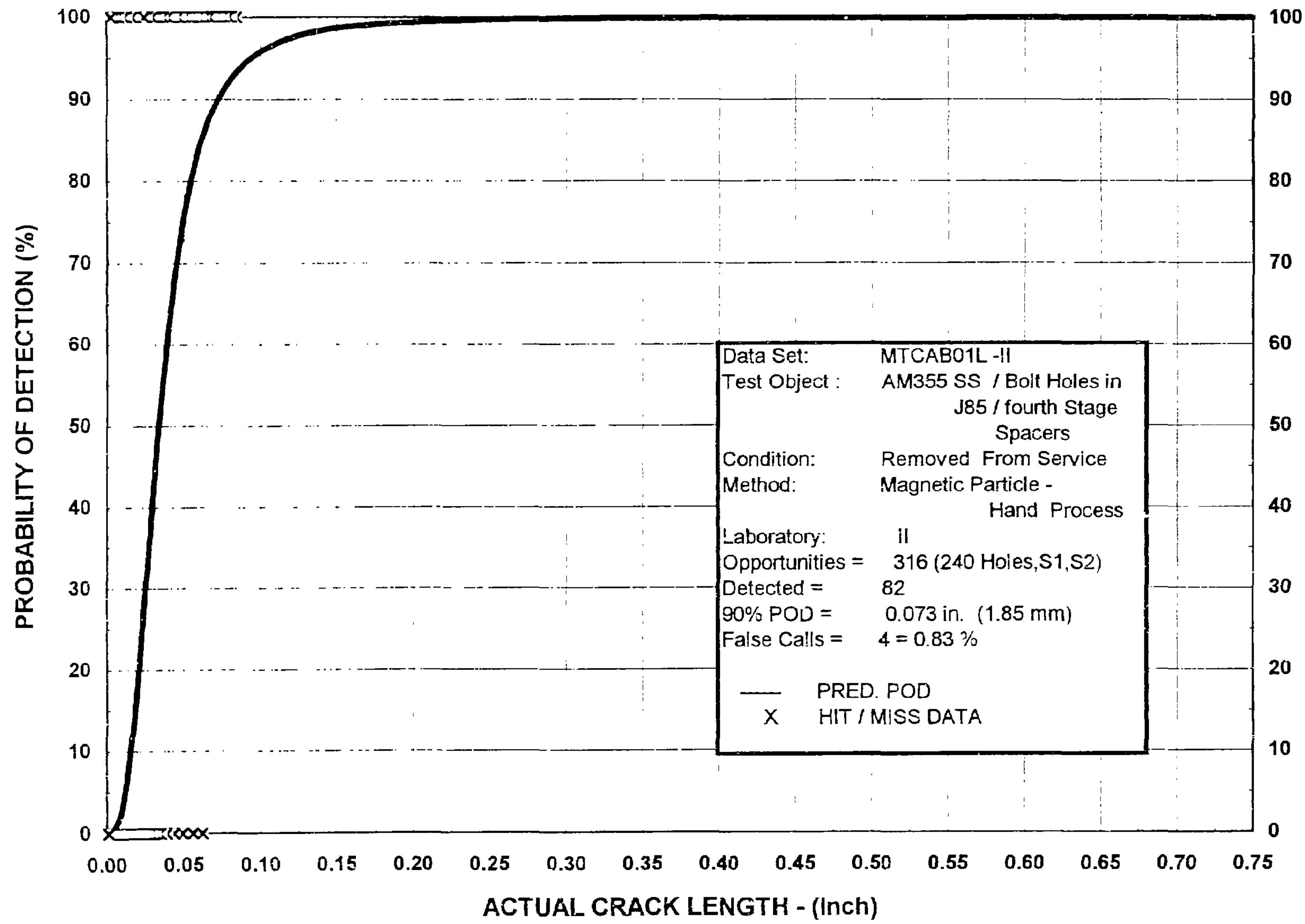

Data Set: MTCAA01L -III
Test Object : AM355 SS / Bolt Holes in J85 / Sixth Stage Disks
Condition: Removed From Service
Method: Magnetic Particle - Hand Process
Laboratory: III
Opportunities = 88 (160 Holes)
Detected = 61
90% POD = 0.045 in. (1.14 mm)
False Calls = 19 = 11.87 %
PRED. POD
X HIT / MISS DATA
PROBABILITY OF DETECTION (%)
ACTUAL CRACK LENGTH - (Inch)
0
10
20
30
40
50
60
70
80
90
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75

MT-03(4)	DATA SET DESCRIPTION
METHOD:	Magnetic Particle
TEST OBJECT TYPE:	Bolt holes in J85 / Fourth stage spacers: 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Magnetic particle per MIL STD 1949A
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	MTCAB01L-I AND MTCAB01L-II
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	ORG I: 240 holes. S1 with 197 cracks ; ORG II: 2400 holes, S1,S2 with 316 cracks
DETECTED:	ORG I: 82; ORG II: 38
FALSE CALLS:	ORG I: 0; ORG II: 4 = 0.83%
REFERENCE:	LTR-ST-1961 Fahr. A., D. Forsyth. M. Bullock and W. Wallace. **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO. Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research. National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG I: 0.237 in. (6.03 mm) ORG II: 0.073 in. (1.85 mm)

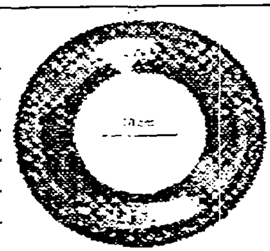


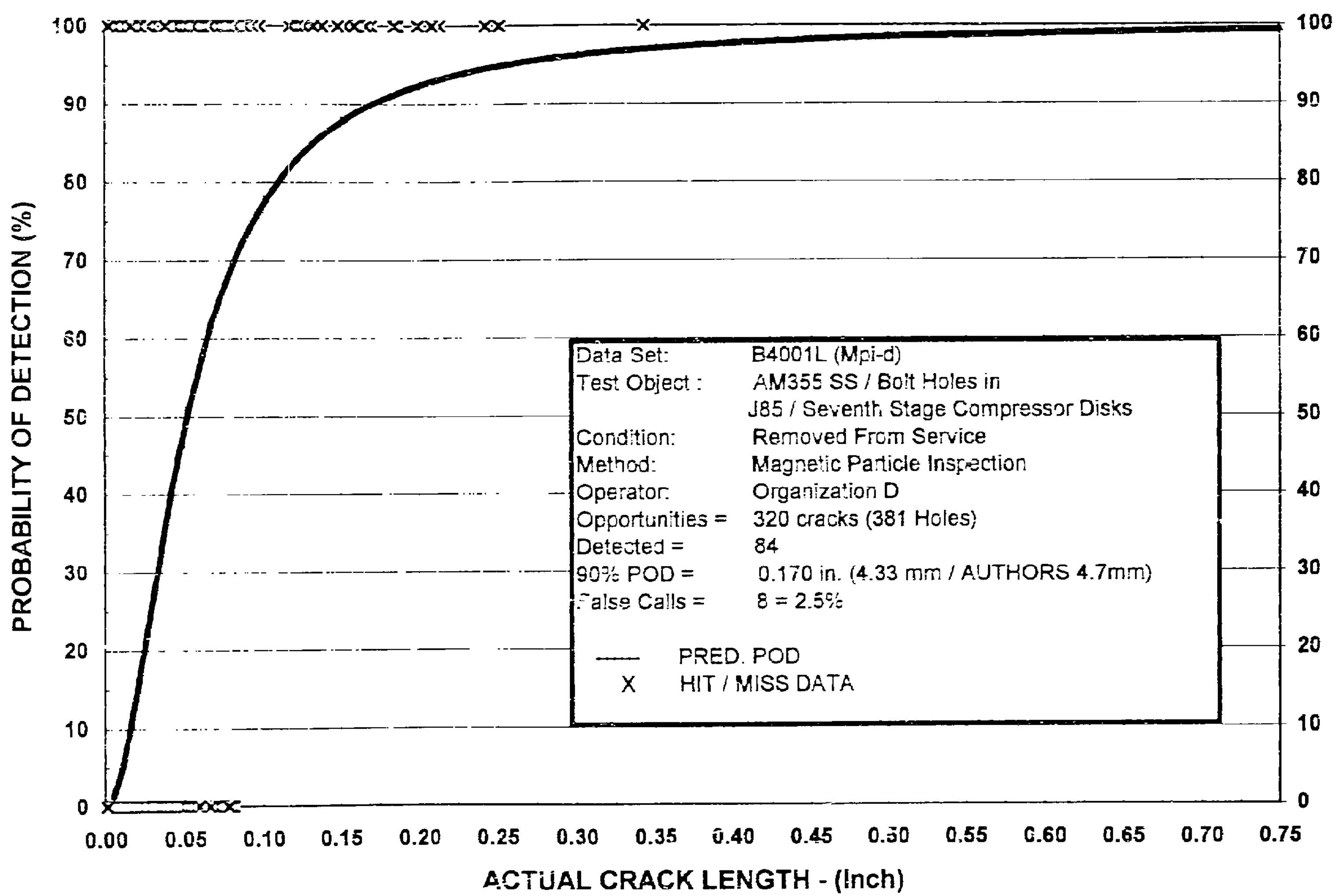
MT-03(4)
6/95

MTCAB01L-I
(ORG. I)



MTCAB01L-II
(ORG. II)

B4000(7)L	DATA SET DESCRIPTION
METHOD:	Magnetic particle inspection
TEST OBJECT TYPE:	Bolt holes in J85 / Seventh stage compressor disks; 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Manual processing, magnetic particle inspection
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual processing
DATA SET IDENTIFIERS:	B4001L
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	381 Holes / 320 cracks
DETECTED:	B4001L - 84
FALSE CALLS:	B4001L - 8
REFERENCE:	LTR-ST-2055, D.S. Forsyth and A. Fahr. **The Sensitivity and Reliability of NDI Techniques for Gas Turbine Components Inspection and Life Prediction**.
DATE:	August, 1996.
WORK SPONSOR:	Department of National Defence, DAS Eng 6-2.
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	The maximum likelihood method of curve fitting used in this databook differs slightly from the algorithm used by the authors. The authors calculated values are shown for reference.
	Maximum differences are shown for those data sets with the greatest variance. The authors noted difficulties fitting such data to the model.
	90% POD ORG D: 0.170 in. (4.33 mm / Authors - 4.7 mm)

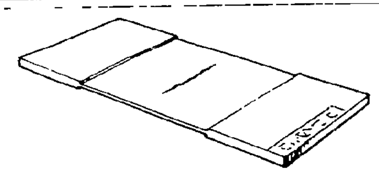


B4001L Service Induced Cracks
ORGANIZATION D

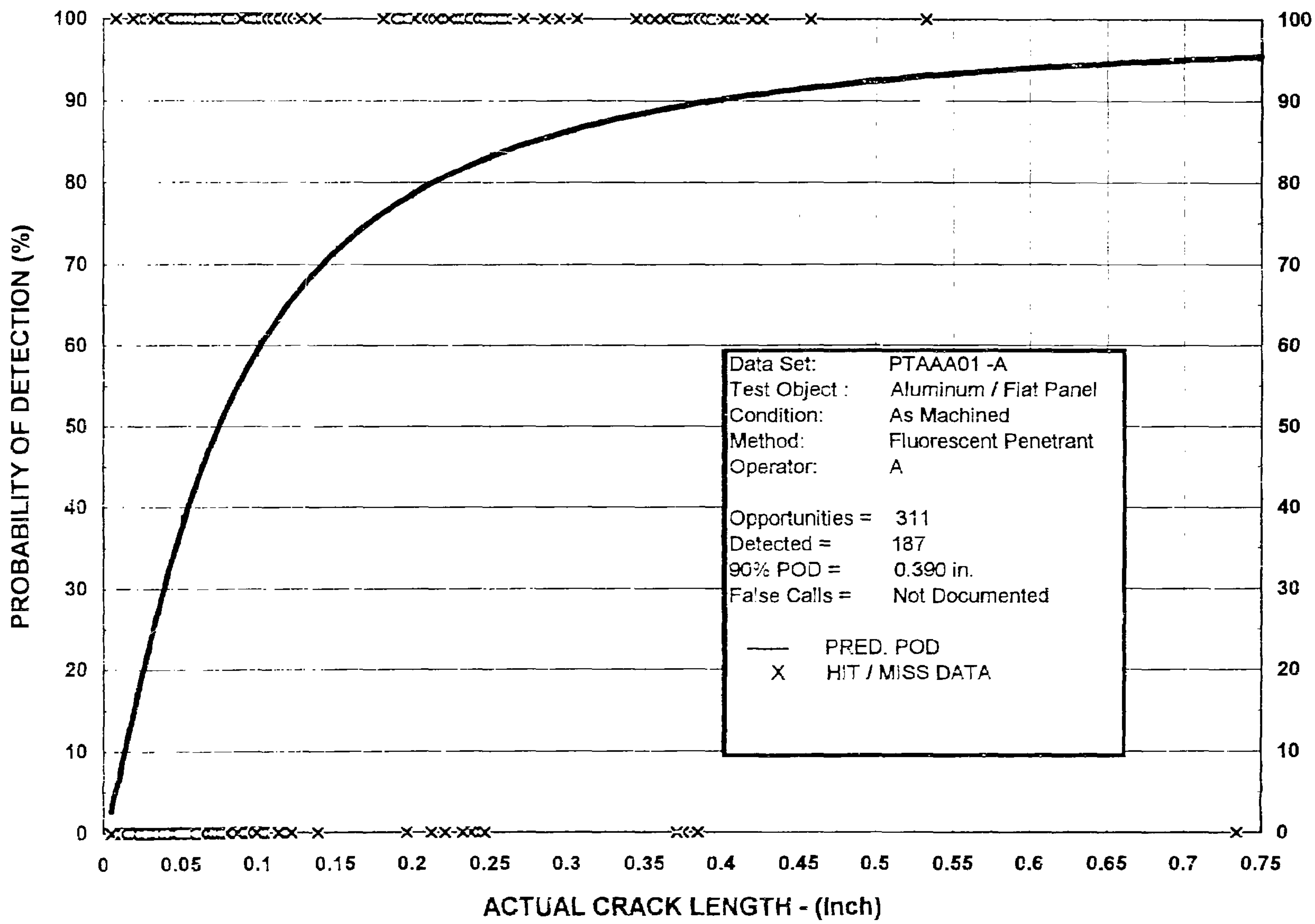
B4000(7) MAGNETIC PARTICLE INSPECTION OF BOLT HOLES

9/96 - B4001L

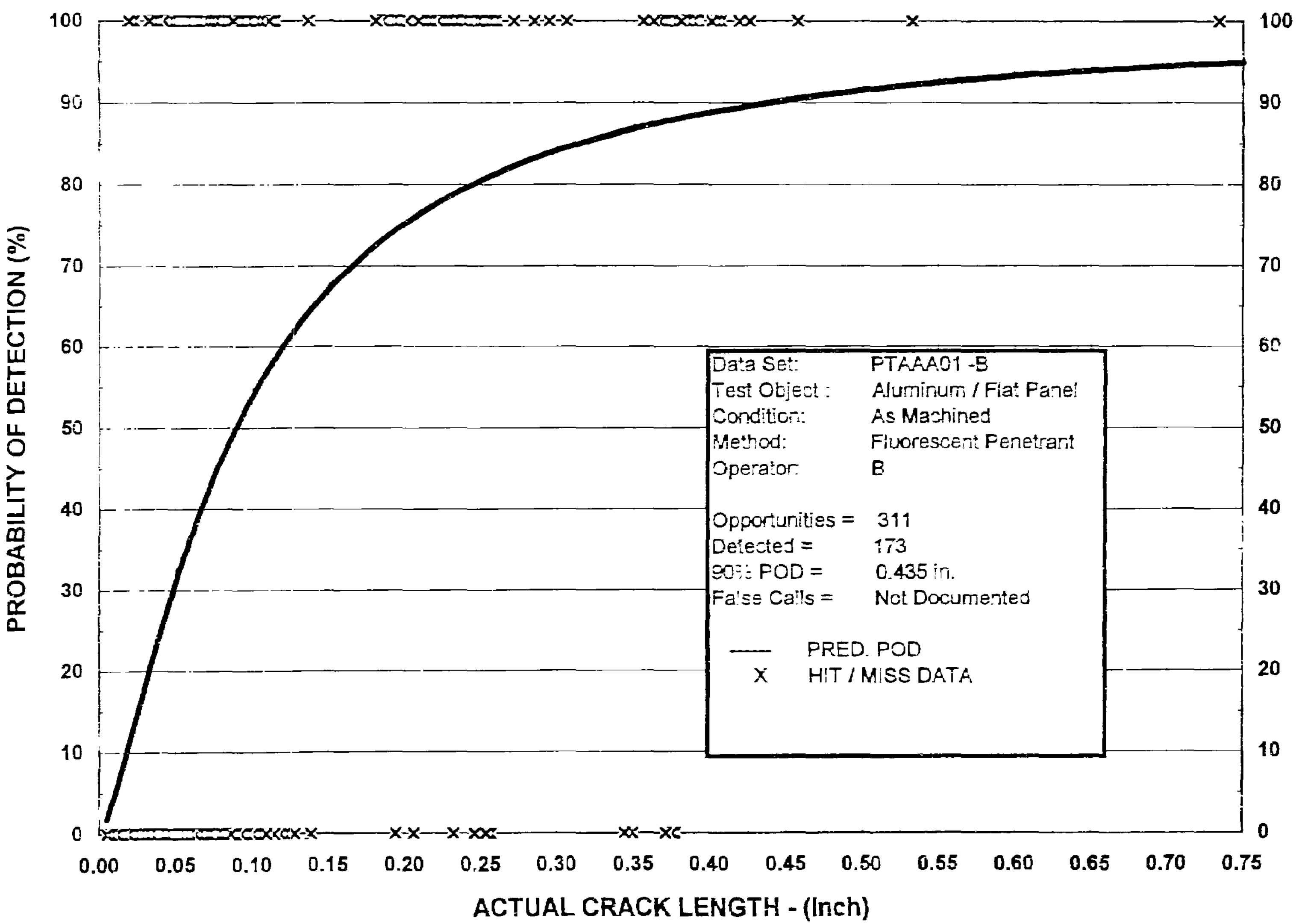
PT - 01 (1)	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches. cracks on both sides
NDE PROCEDURE:	Fluorescent Penetrant Manual - URESCO P149, Solvent Removable, Spray Developer
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,"After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	PTAAA01-A,B,C; PTAAA02-A,B,C; PTAAA03-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	311 Cracks
DETECTED:	PTAAA01-A= 187, B= 173, C= 233; 02-A= 272, B= 277, C= 260; 03-A= 282, B= 280, C= 260
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.



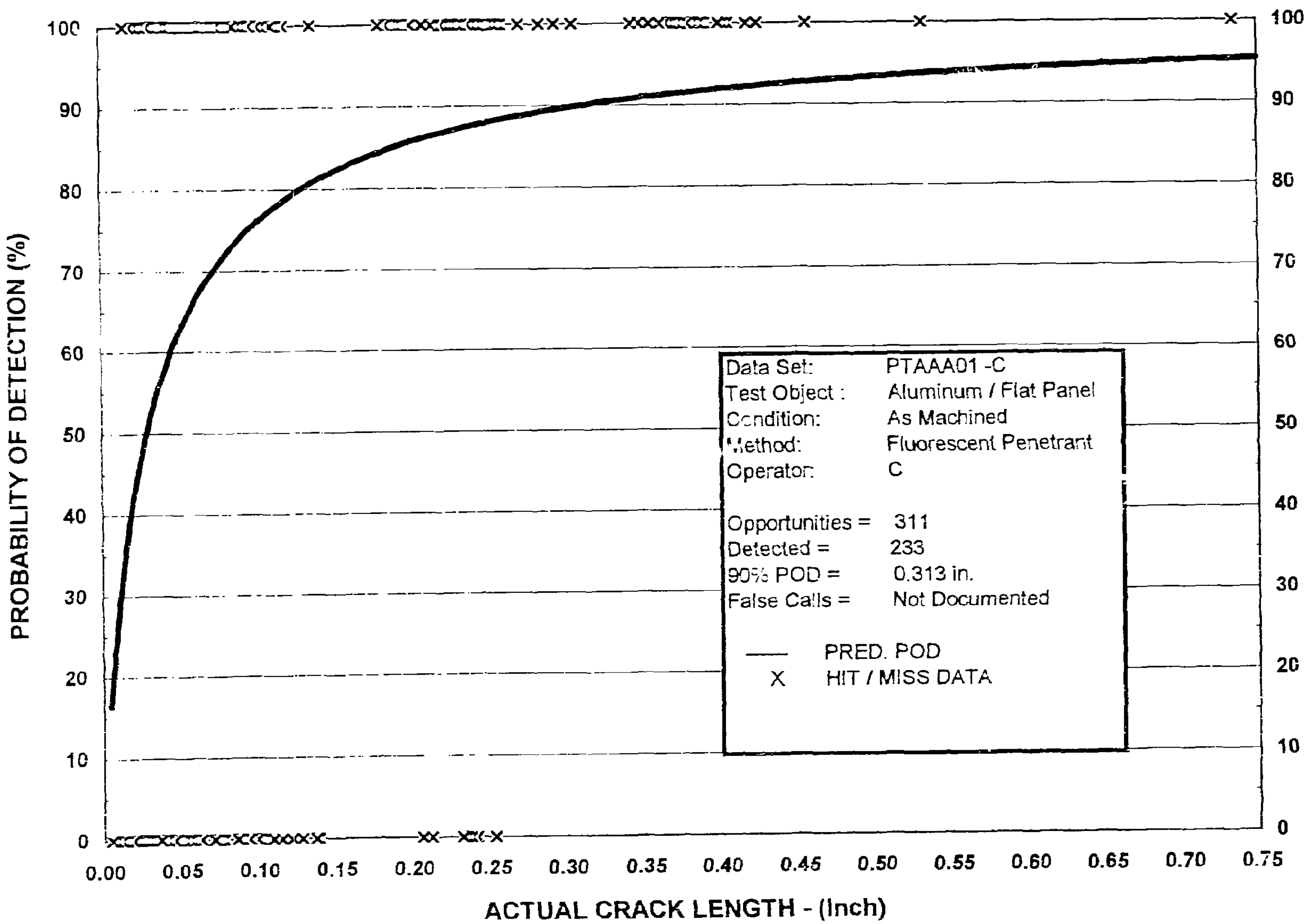
90% POD	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= 0.390 in.	A= 0.089 in.	A= 0.017 in.
	B= 0.435 in.	B= 0.077 in.	B= 0.059 in.
	C= 0.313 in.	C= 0.106 in.	C= 0.077 in.



100
90
80
70
60
50
40
30
20
10
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
PROBABILITY OF DETECTION (%)
ACTUAL CRACK LENGTH - (Inch)
Data Set: PTAAA01 -A
Test Object : Aluminum / Flat Panel
Condition: As Machined
Method: Fluorescent Penetrant
Operator: A
Opportunities = 311
Detected = 187
90% POD = 0.390 in.
False Calls = Not Documented
PRED. POD
X HIT / MISS DATA

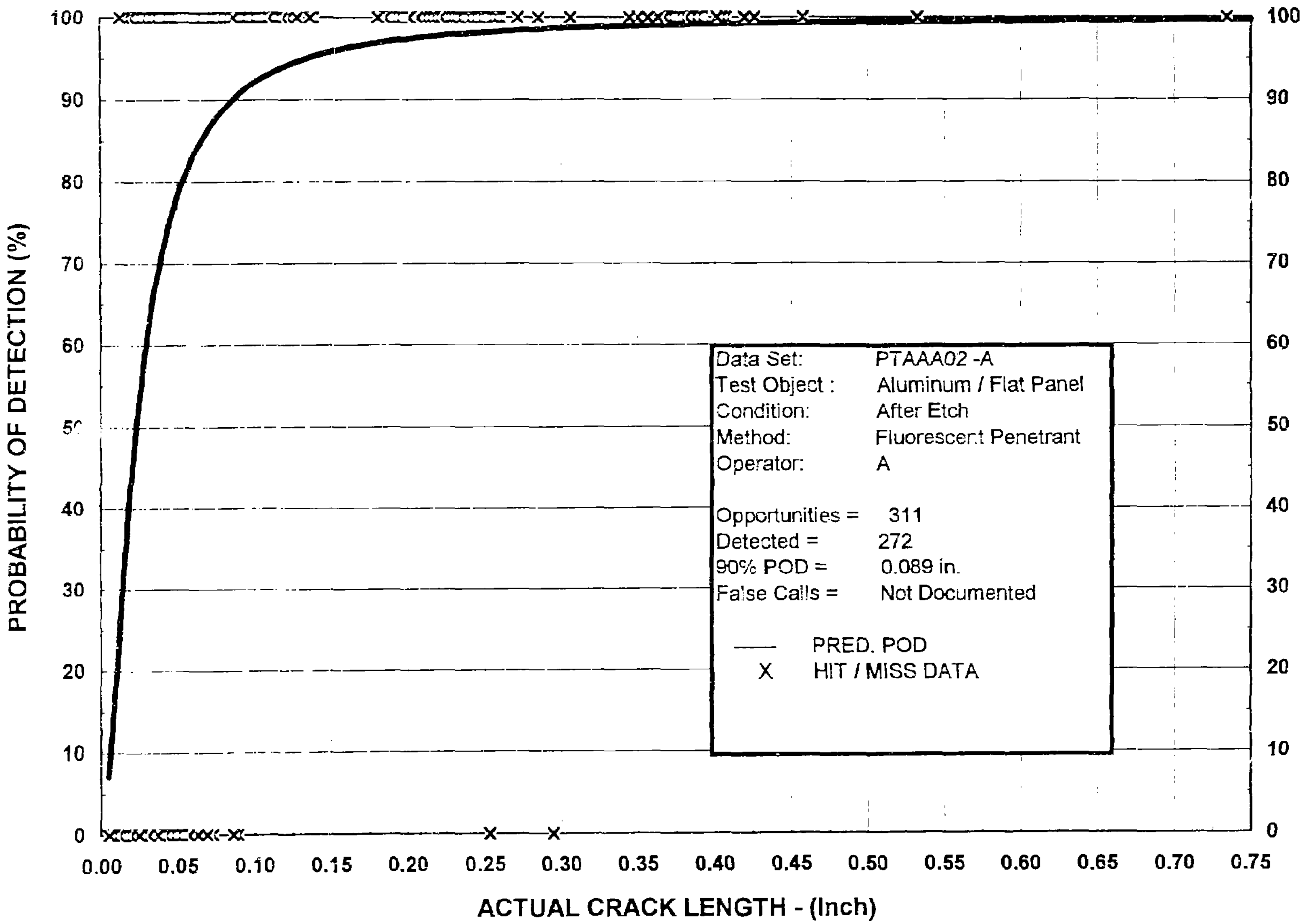


PTAAA01-B
Aluminum - Flat Panel



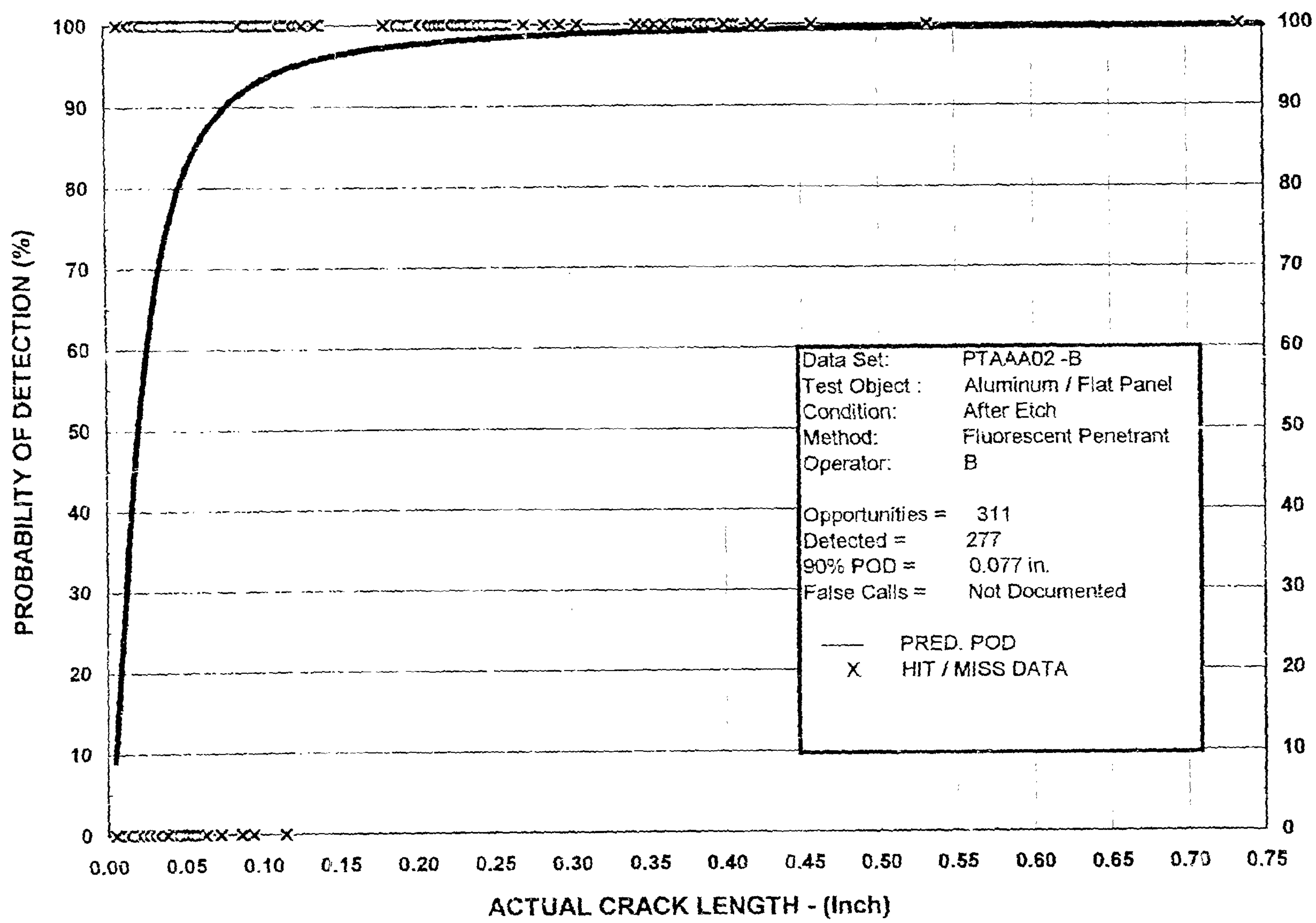
PT - 01 (1)
6/95

PTAAA01-C
Aluminum - Flat Panel

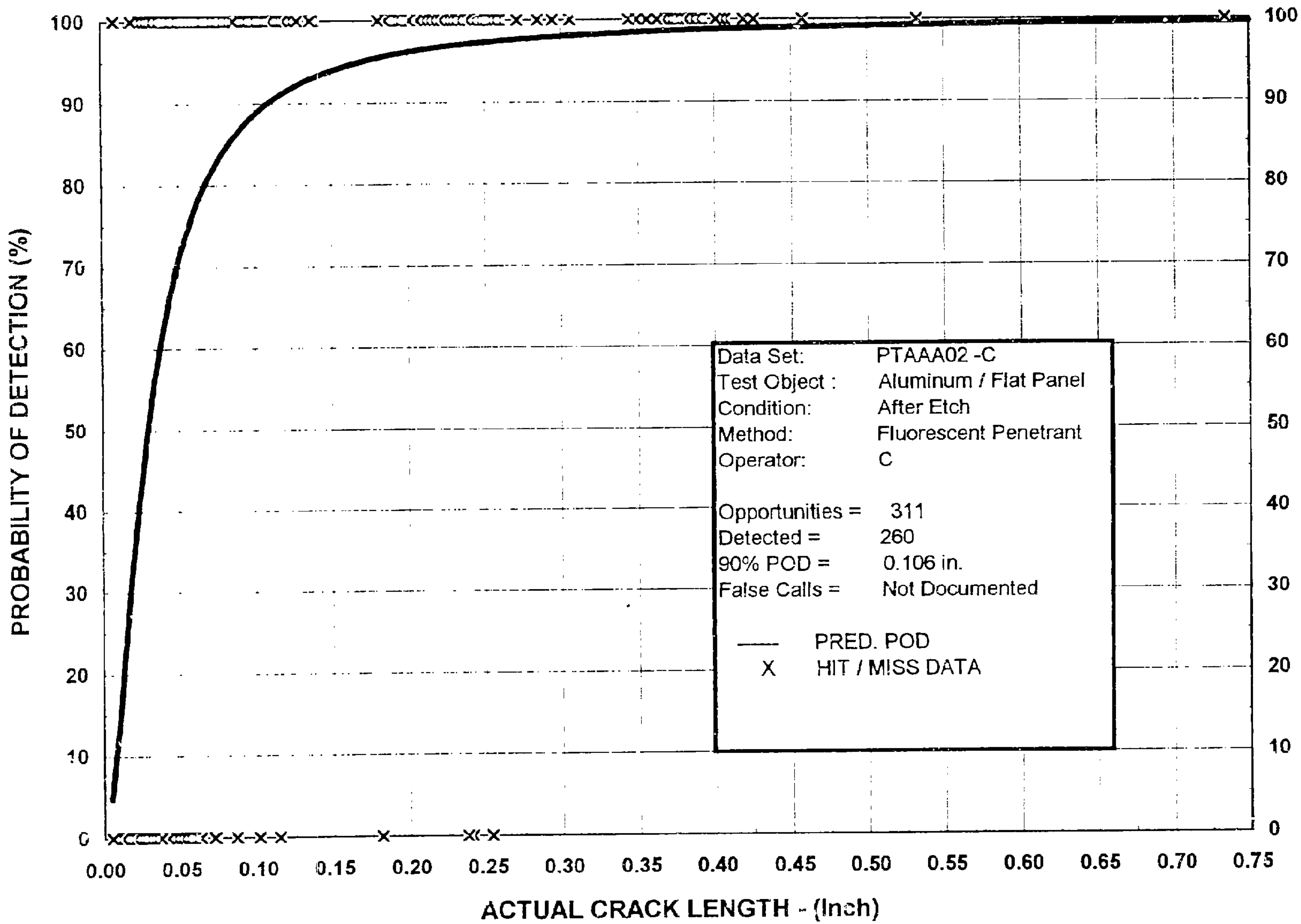


PT - 01 (1)
6/95

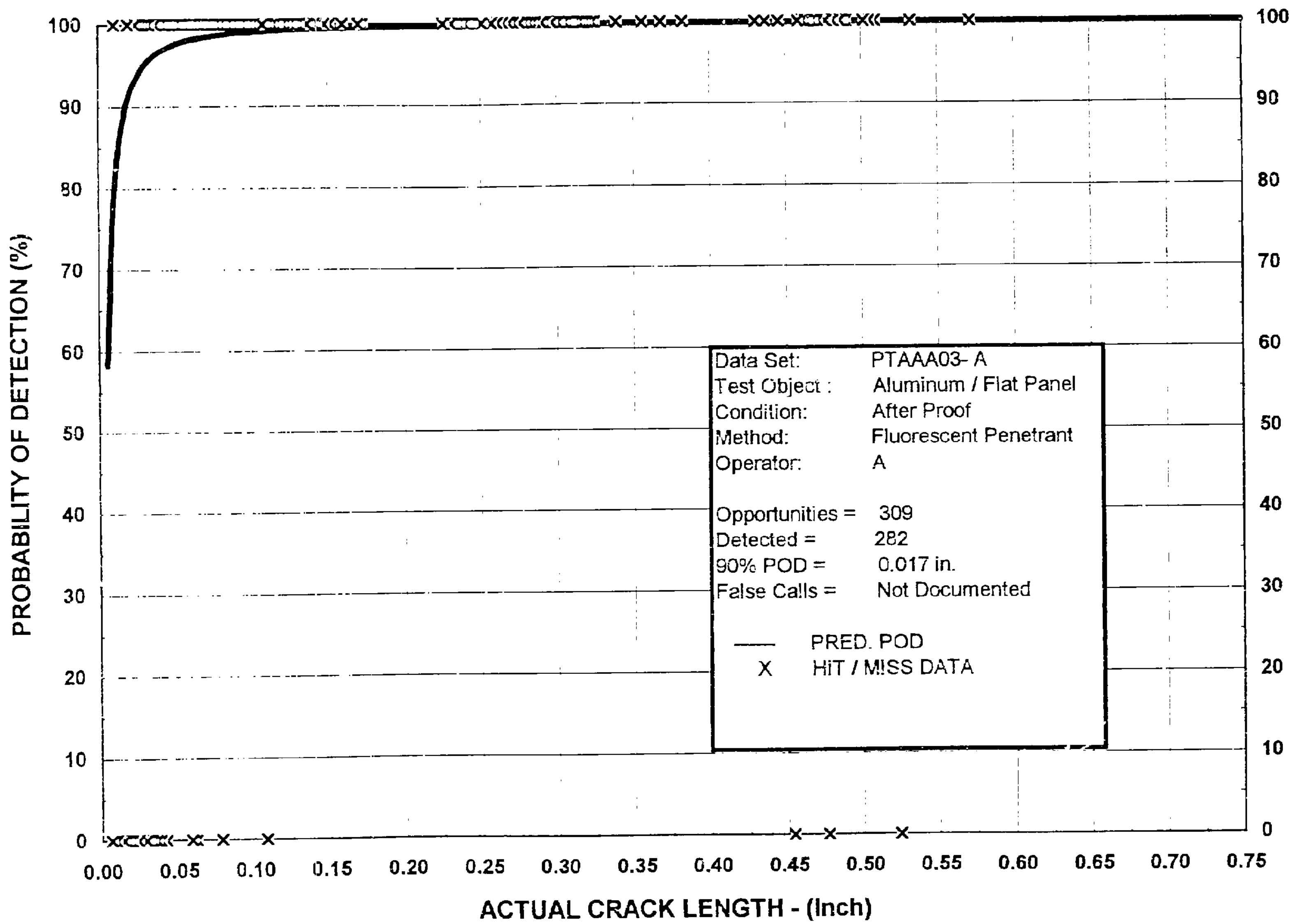
PTAAA02-A
Aluminum - Flat Panel



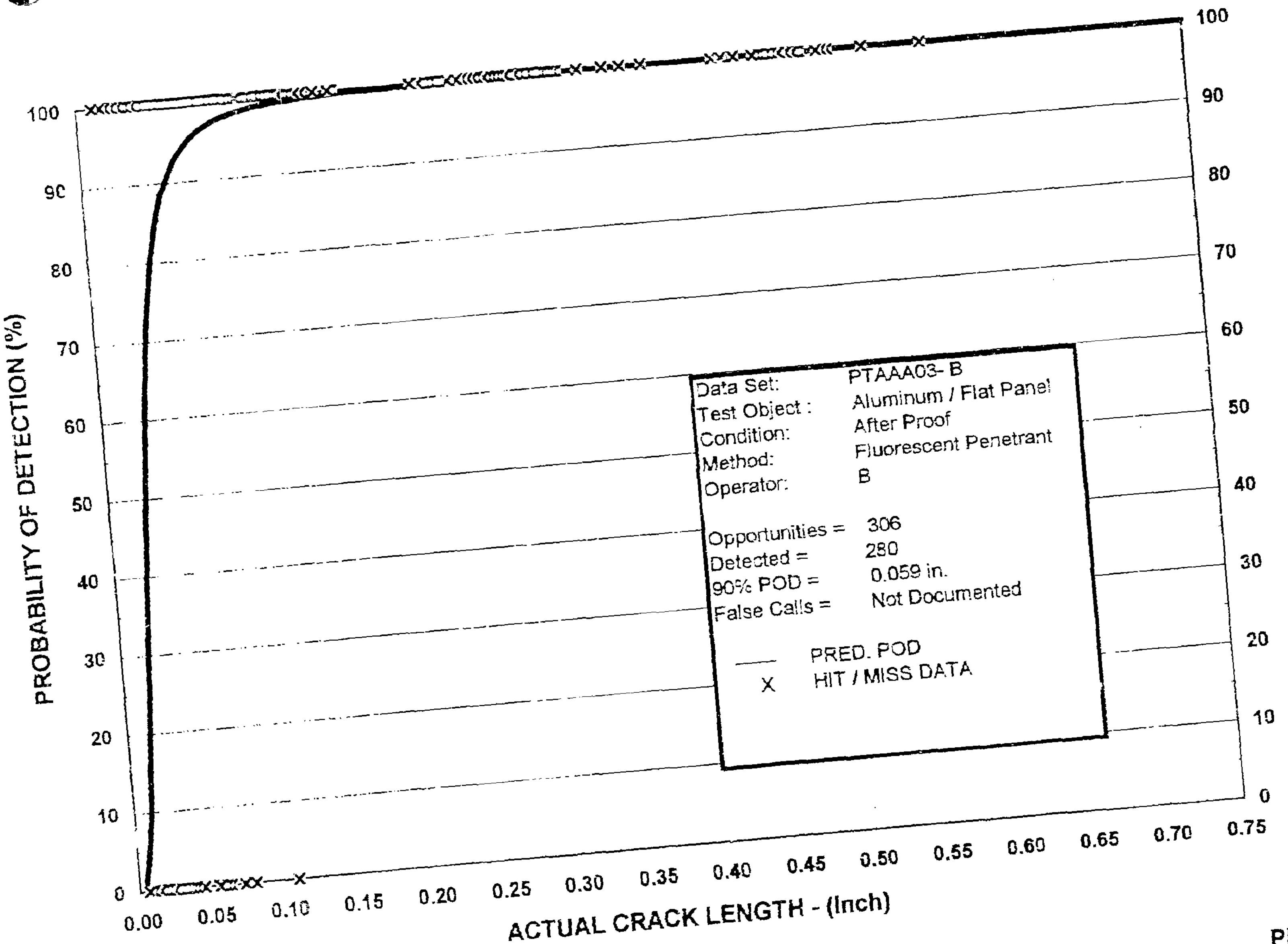
PTAAA02-B
Aluminum - Flat Panel



PTAAA02-C
Aluminum - Flat Panel

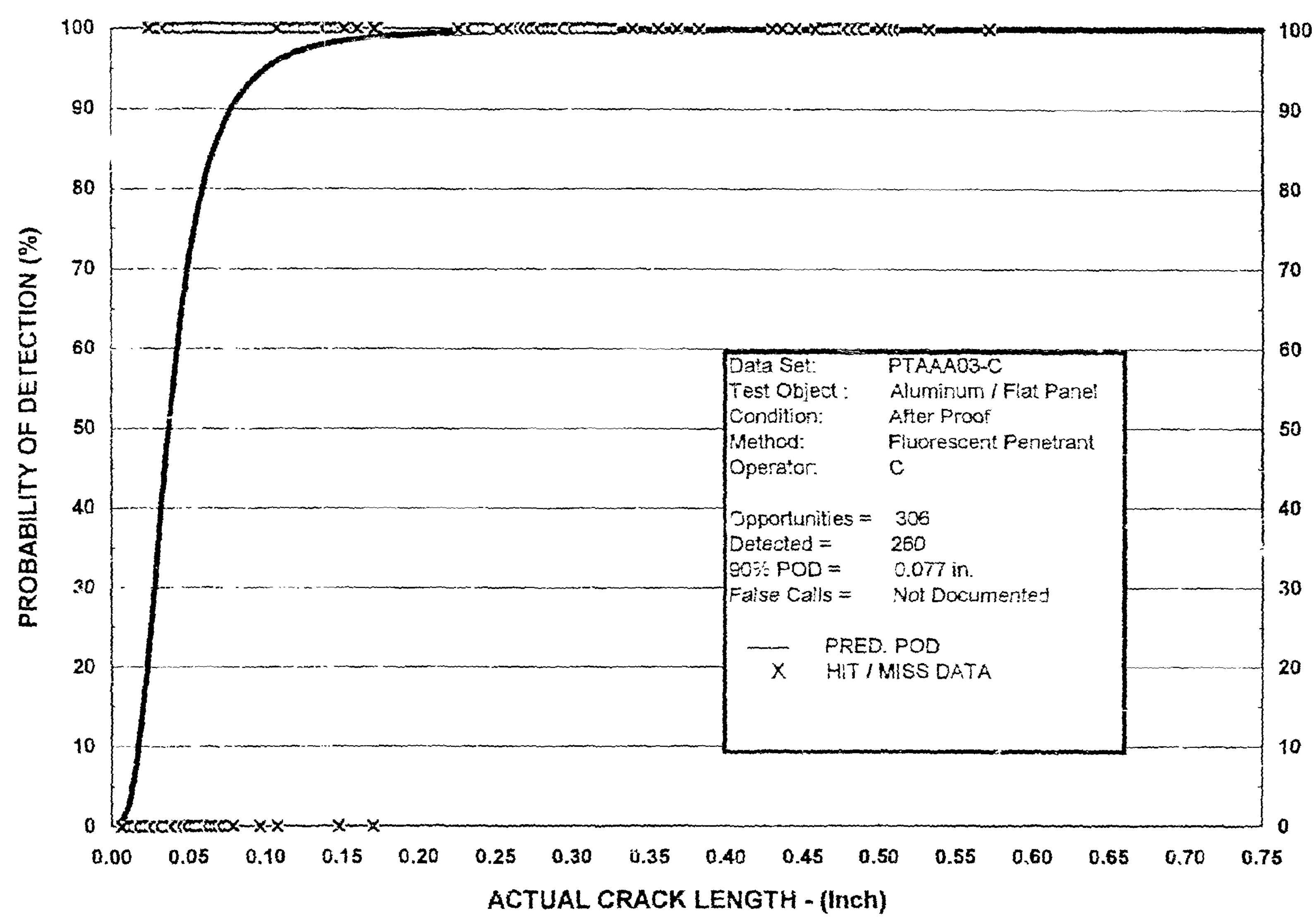


PTAAA03-A
Aluminum - Flat Panel



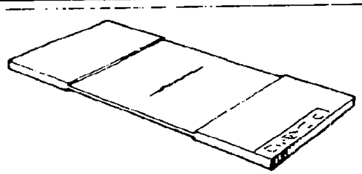
PFAAA03-B
Aluminum - Flat Panel

PT 01 (1)
6/95



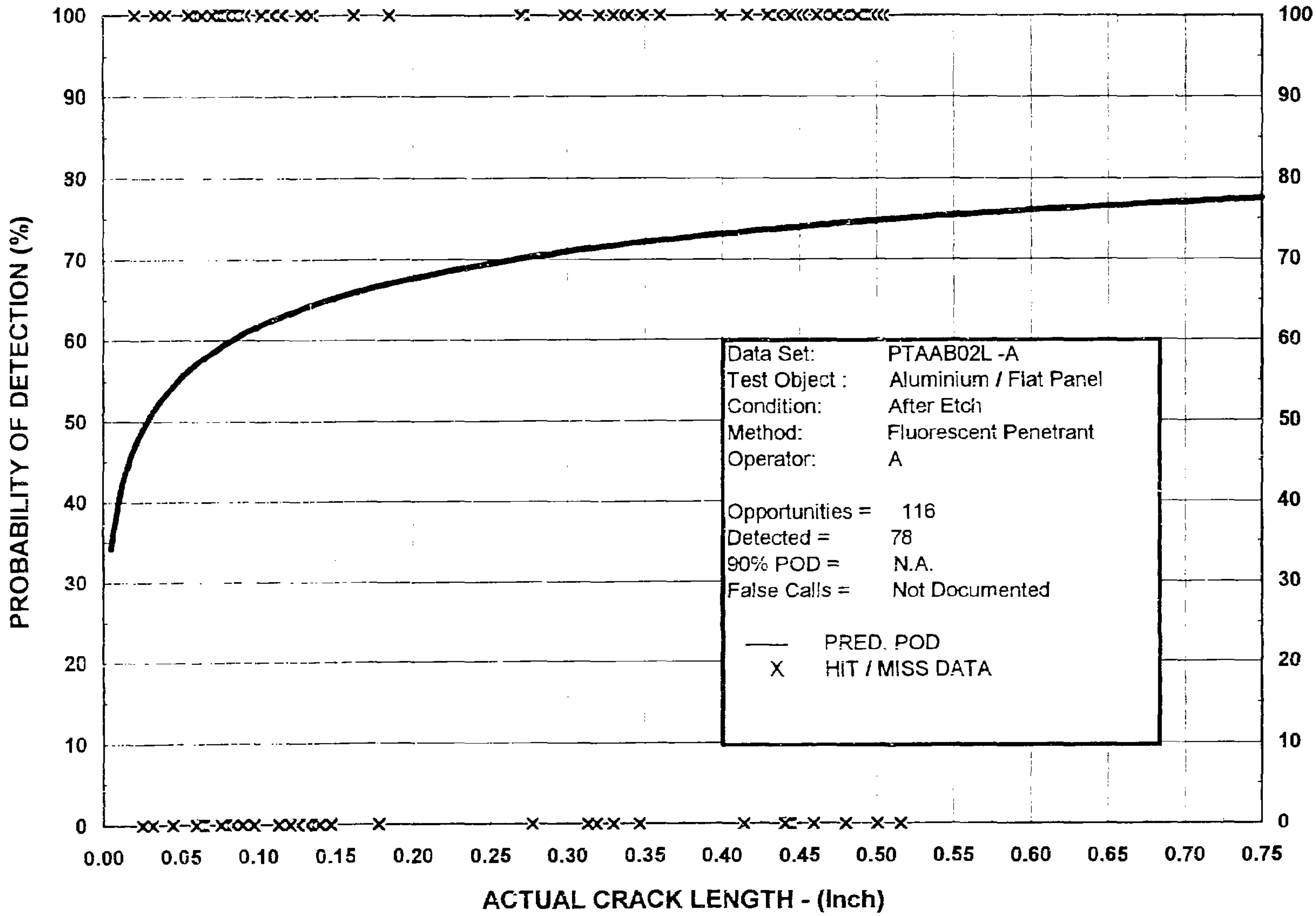
PT 01 (1)
6/95

PTAAA03-C
Aluminum - Flat Panel

PT - 02 (1)	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches. cracks on both sides (General Dynamics Panels)
NDE PROCEDURE:	Fluorescent Penetrant Manual - URESCO P149, Solvent Removable, Spray Developer
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	02,"After Etch"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	PTAAB02-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	116 Cracks
DETECTED:	PTAAB02L-A= 78, B= 108, C= 94
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**
	90% POD "AFTER ETCH" A= N.A. B= 0.094 in. C= 0.218 in.

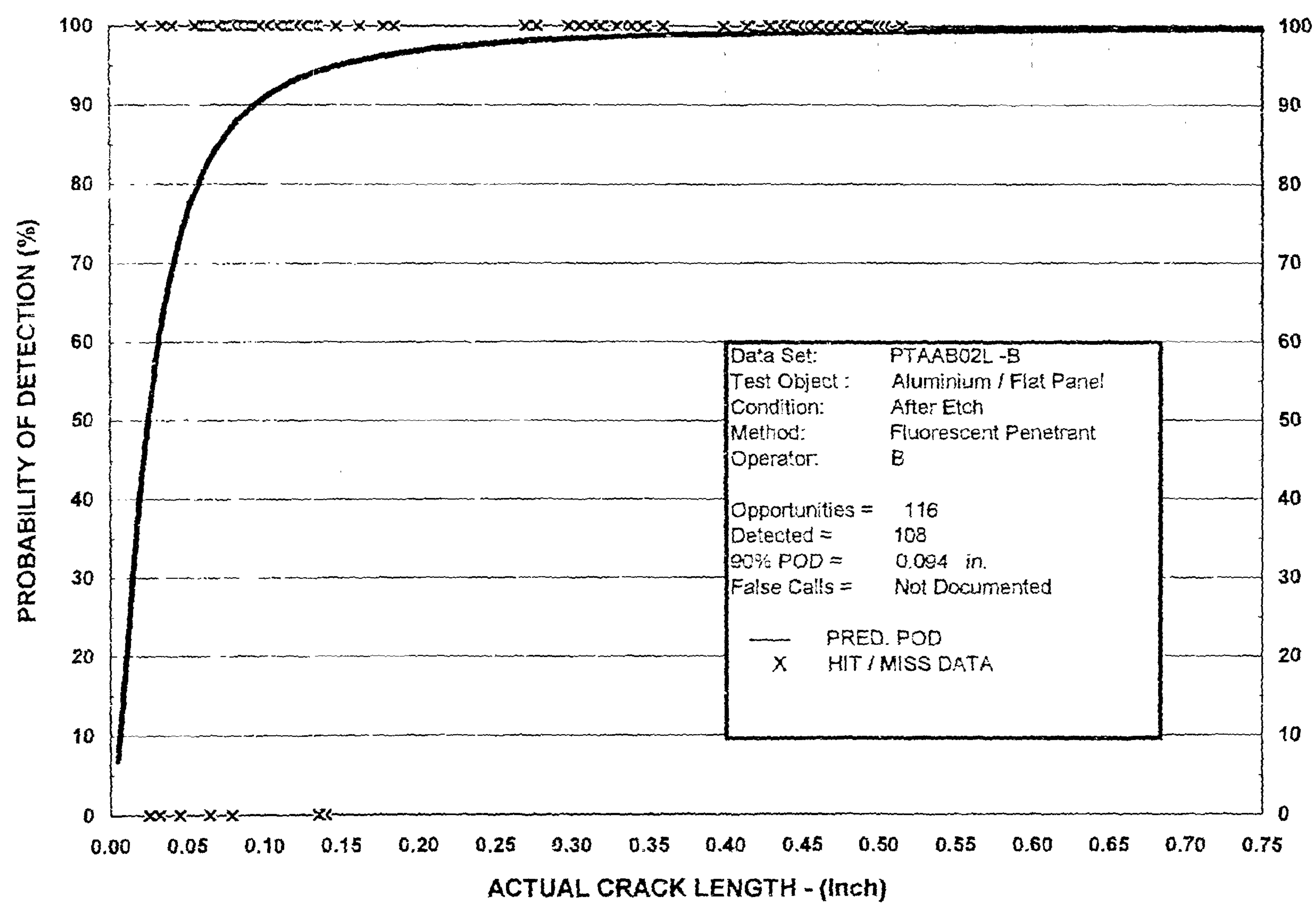
PT - 02 (1) GENERAL DYNAMICS
6/95

FLUORESCENT PENETRANT
ALUMINUM - FLAT PANELS



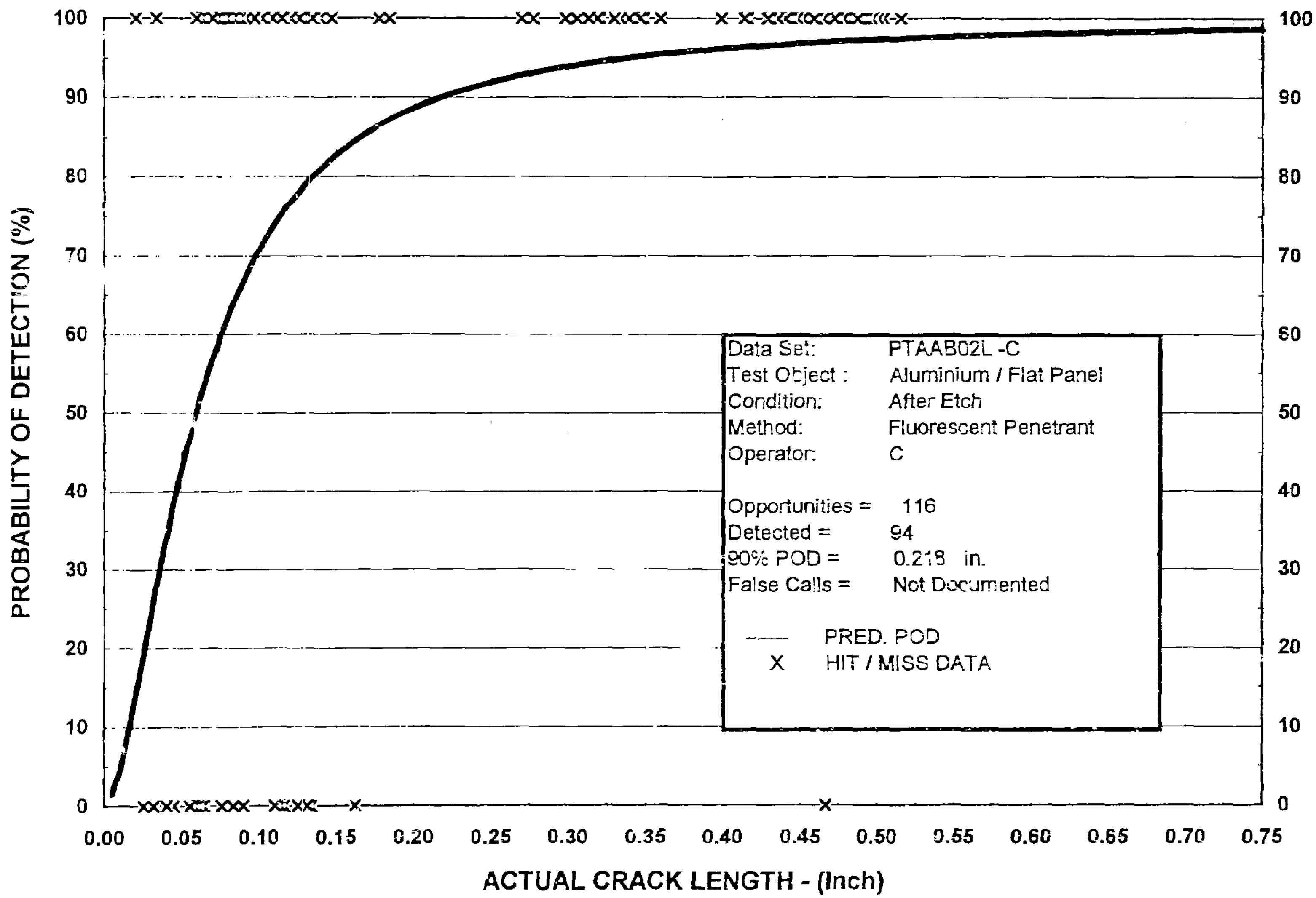
PT-02 (1) FLUORESCENT PENETRANT INSPECTION
GENERAL DYNAMICS ALUMINUM PANELS
6/95

PTAAB02L-A
AFTER ETCH - OPERATOR A



PT-02 (1) FLUORESCENT PENETRANT INSPECTION
GENERAL DYNAMICS ALUMINUM PANELS
6/95

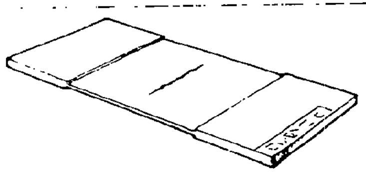
PTAAB02L-B
AFTER ETCH - OPERATOR B



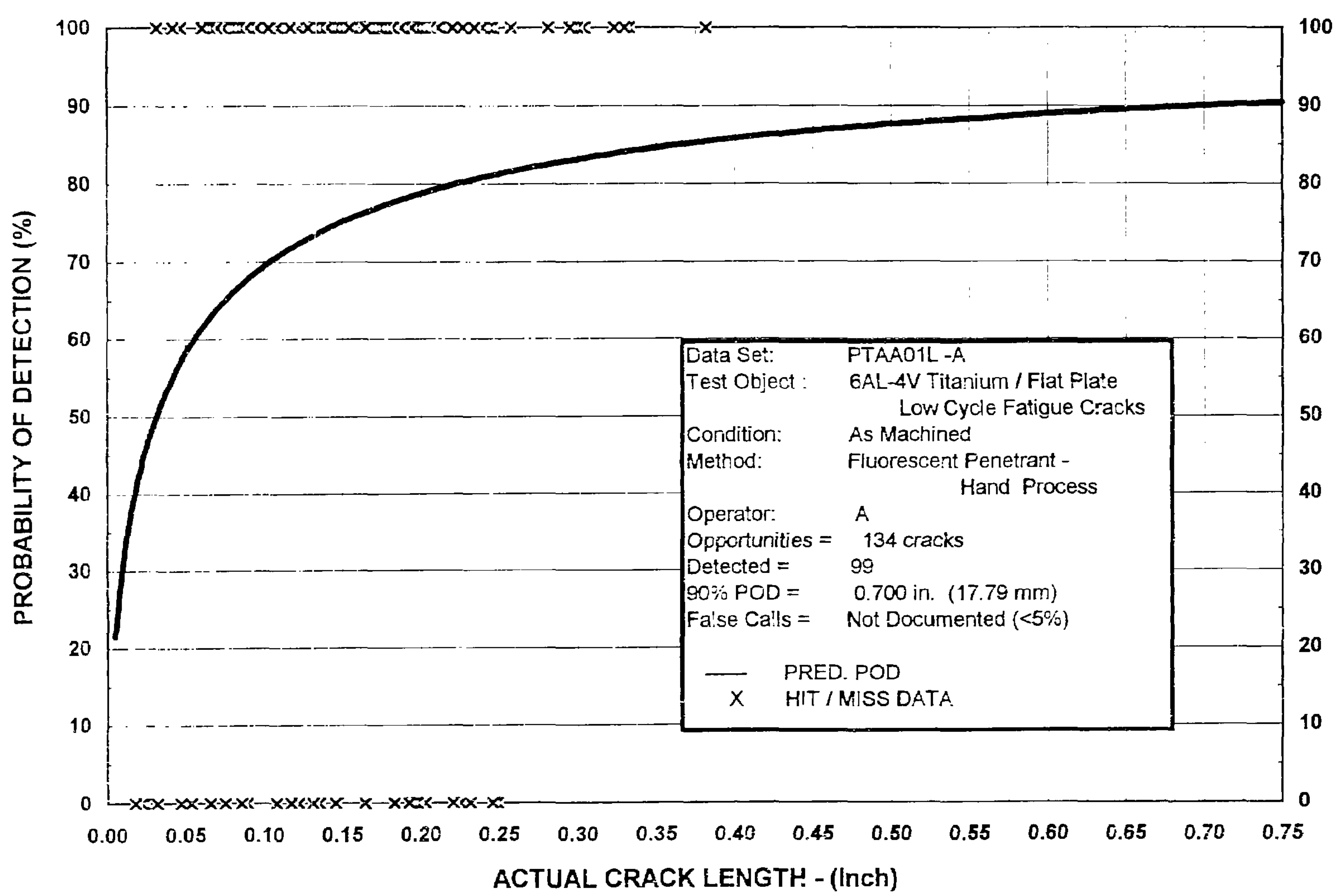
PT-02 (1) FLUORESCENT PENETRANT INSPECTION
GENERAL DYNAMICS ALUMINUM PANELS
6/95

PTAAB02L-C
AFTER ETCH - OPERATOR C

PT 03 (2)	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Fluorescent Penetrant Manual - URESCC P149, Solvent Removable, Spray Developer
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Titanium plate - 6Al4V
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,B1"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual inspection / Manual Recording
DATA SET IDENTIFIER:	PTAA01L - A,B,C; PTAA02L - A,B,C; PTAA03L - A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	134 Cracks (161 original - Some cracks lost in machining)
DETECTED:	PTAA01L - A = 99, B= 119, C= 119; 02L - A= 120,B= 119,C= 126; 03L - A= 116,B= 118,C= 118
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.

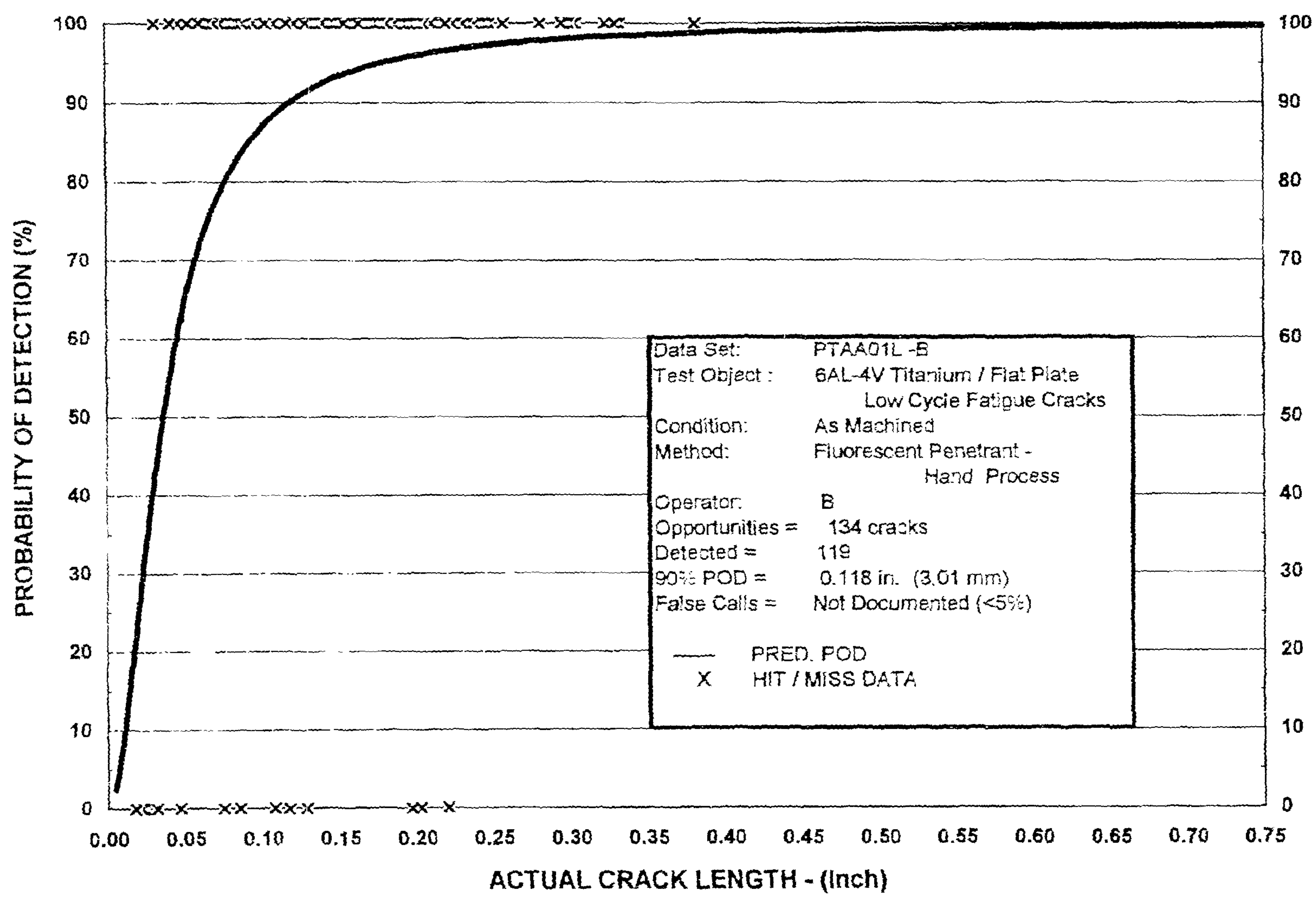


90% POD	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= 0.700 in. (17.79 mm)	A= 0.130 in. (3.30 mm)	A= 0.182 in (4.63 mm)
	B= 0.118 in. (3.01 mm)	B= 0.115 in. (2.93 mm)	B= 0.151 in. (3.84 mm)
	C= 0.139 in. (3.53 mm)	C= 0.077 in. (1.97 mm)	C= 0.153 in. (3.88 mm)



PTAA01L-A
AS MACHINED - OPERATOR A

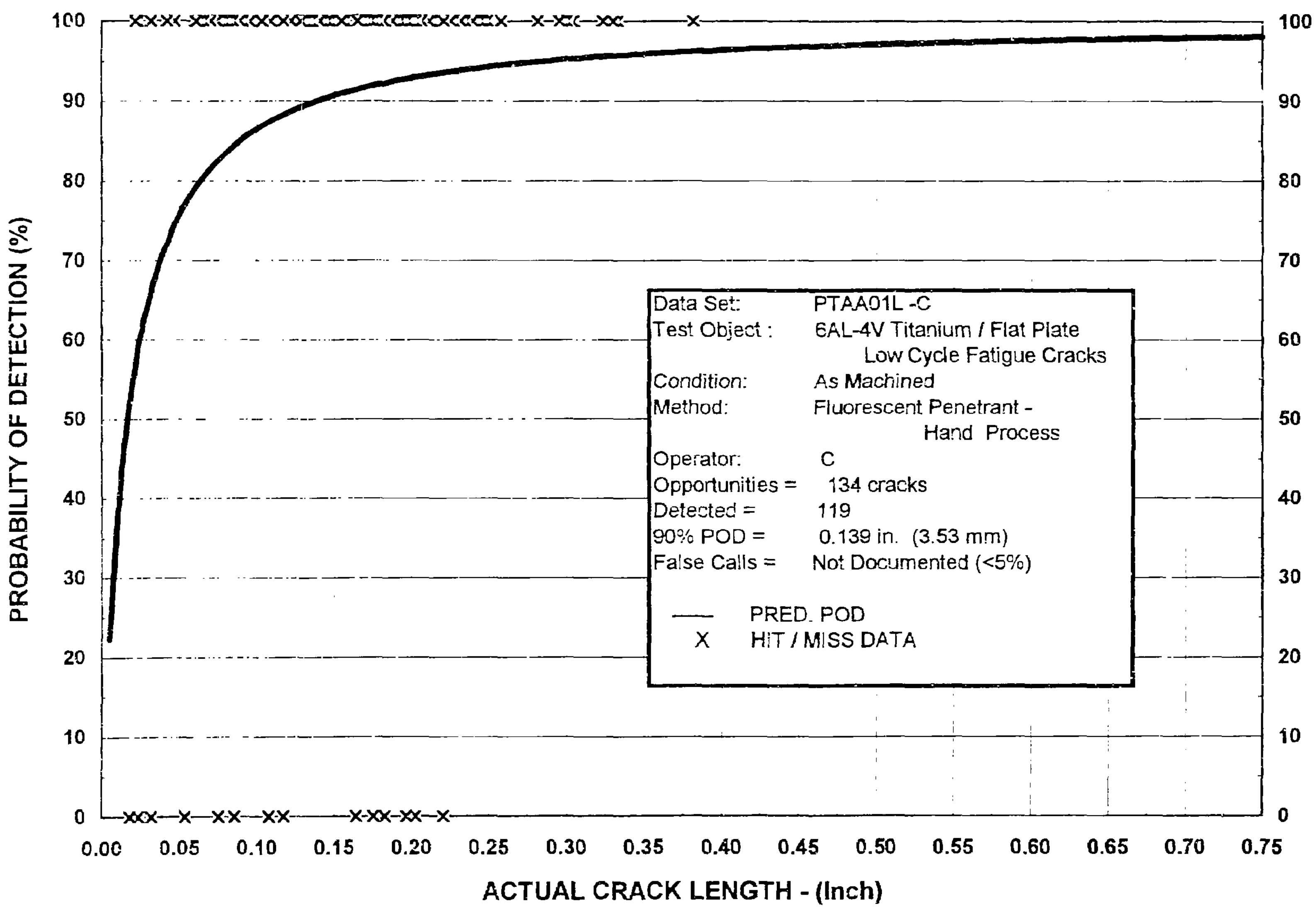
PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS
6/95



PTAA01L-B
AS MACHINED - OPERATOR B

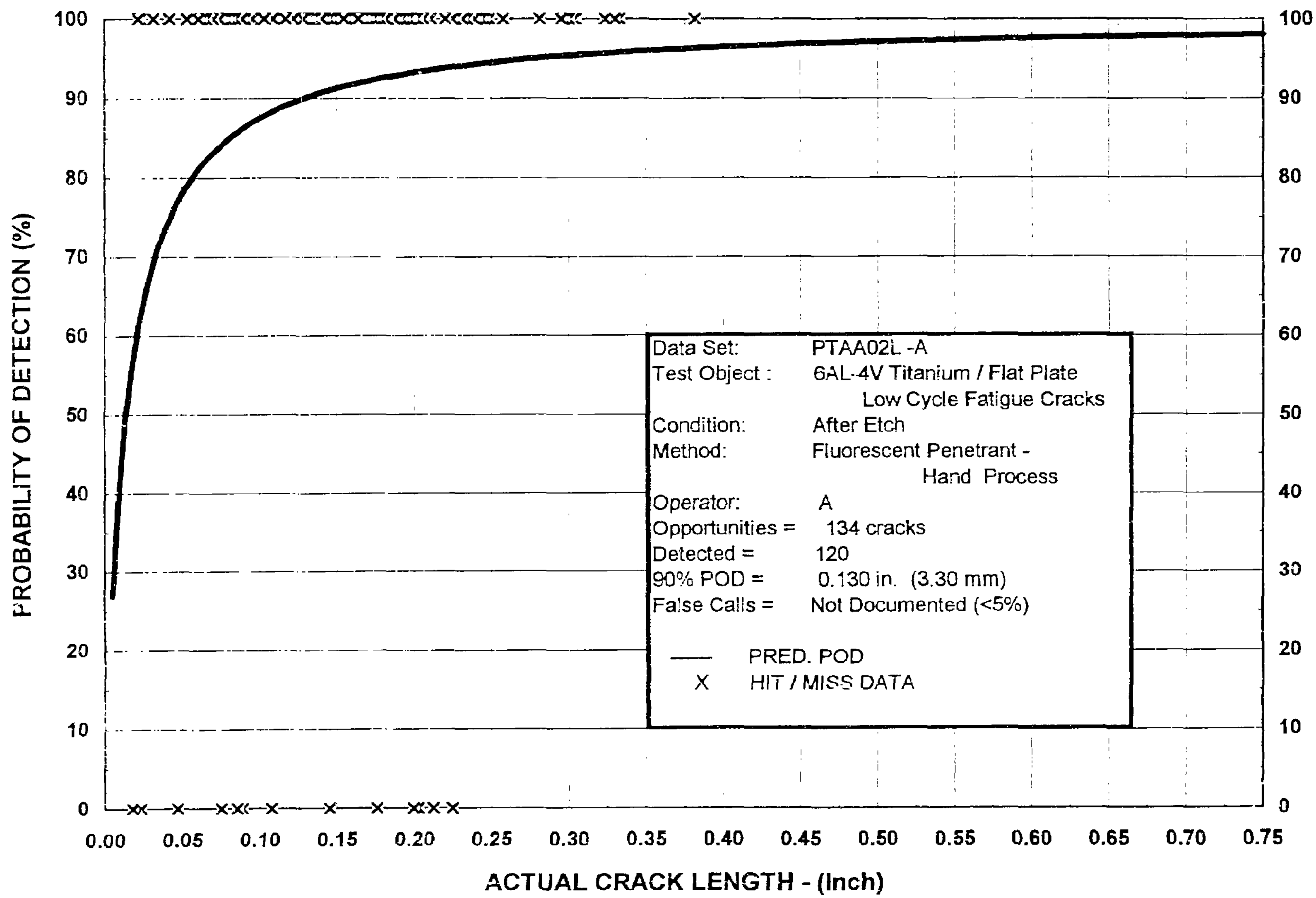
PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS

6/95



PTAA01L-C
AS MACHINED - OPERATOR C

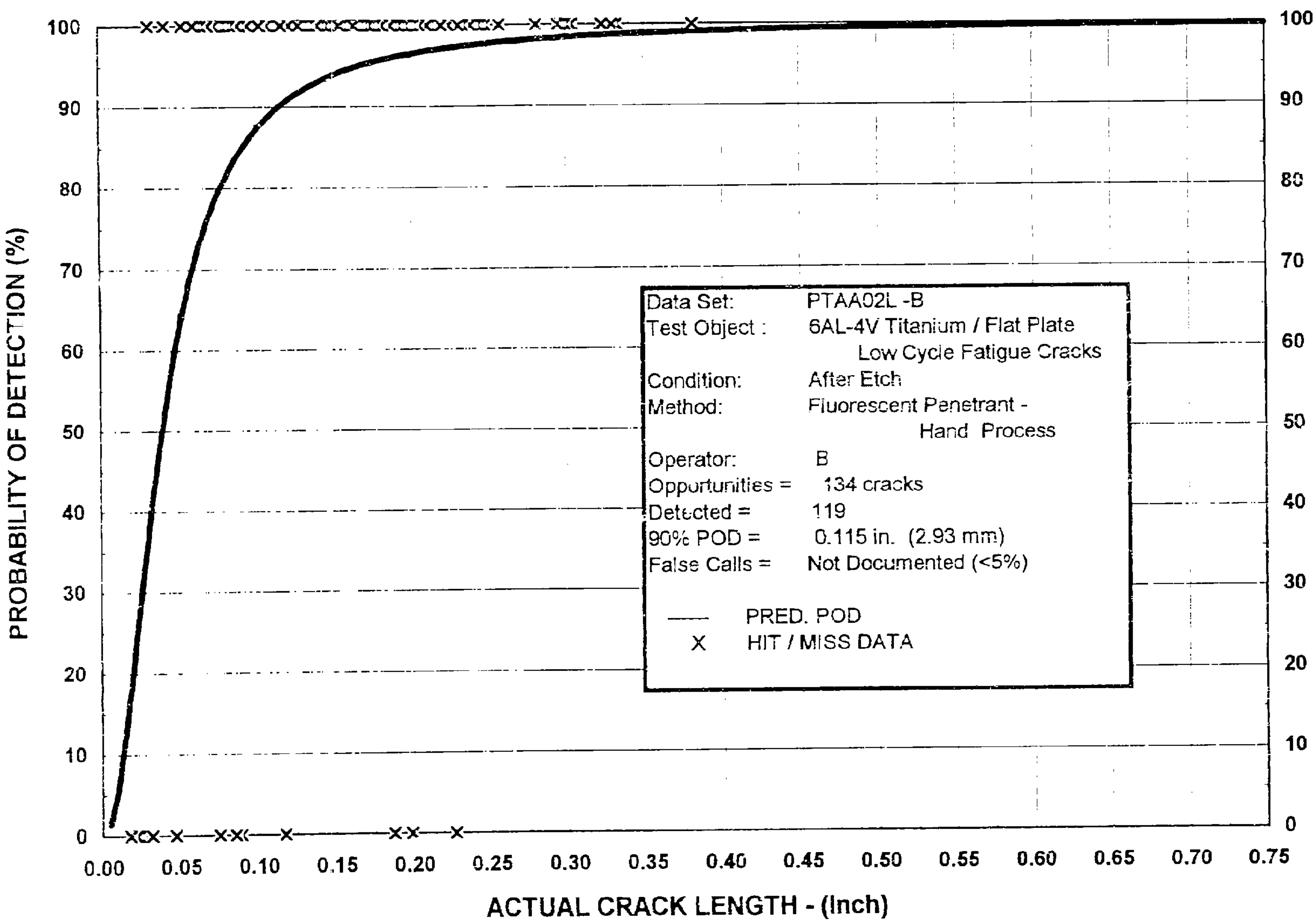
PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS
6/95



PTAA02L-A
AFTER ETCH - OPERATOR A

PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS

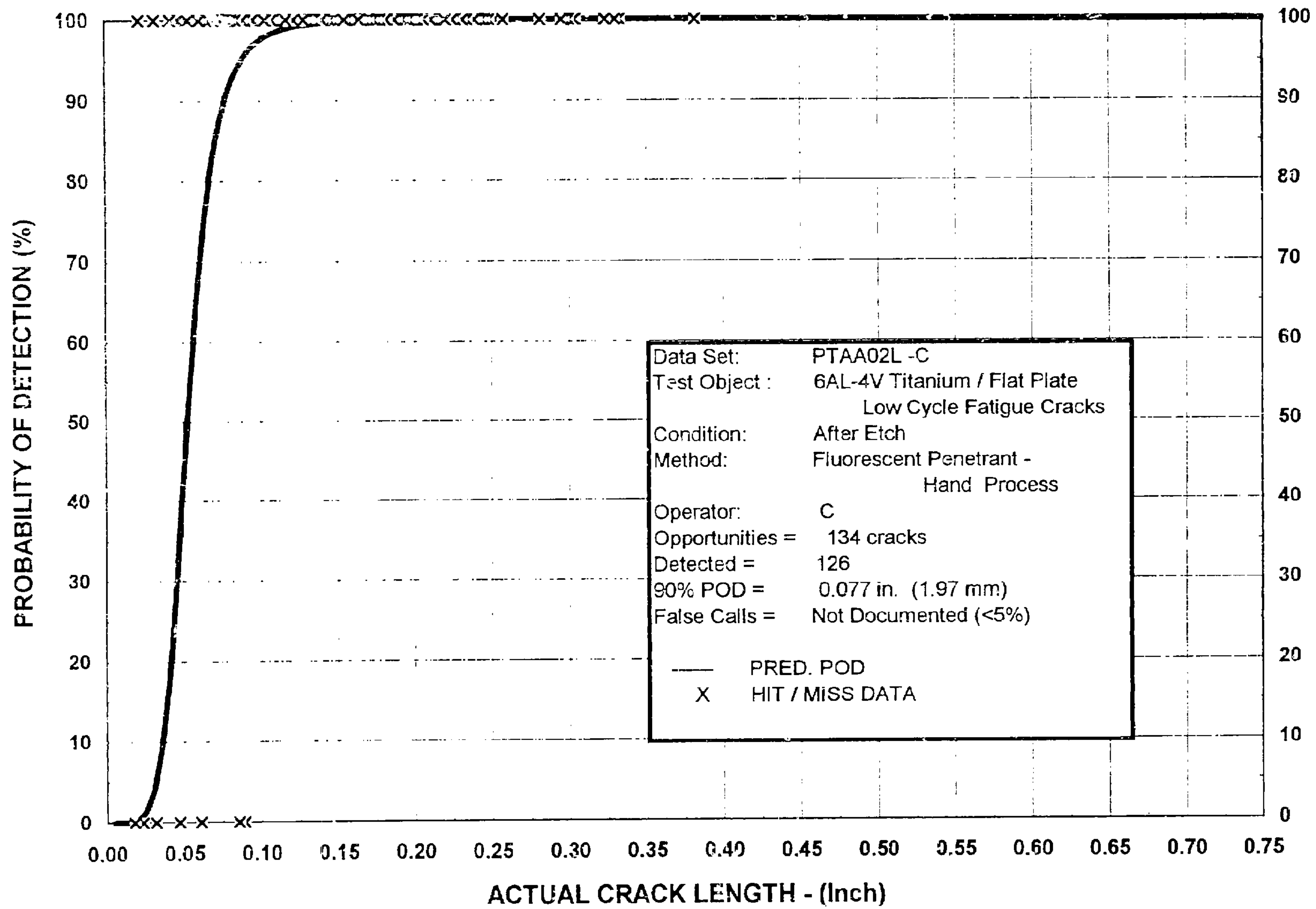
6/95



PTAA02L-B
AFTER ETCH - OPERATOR B

PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS

6/95

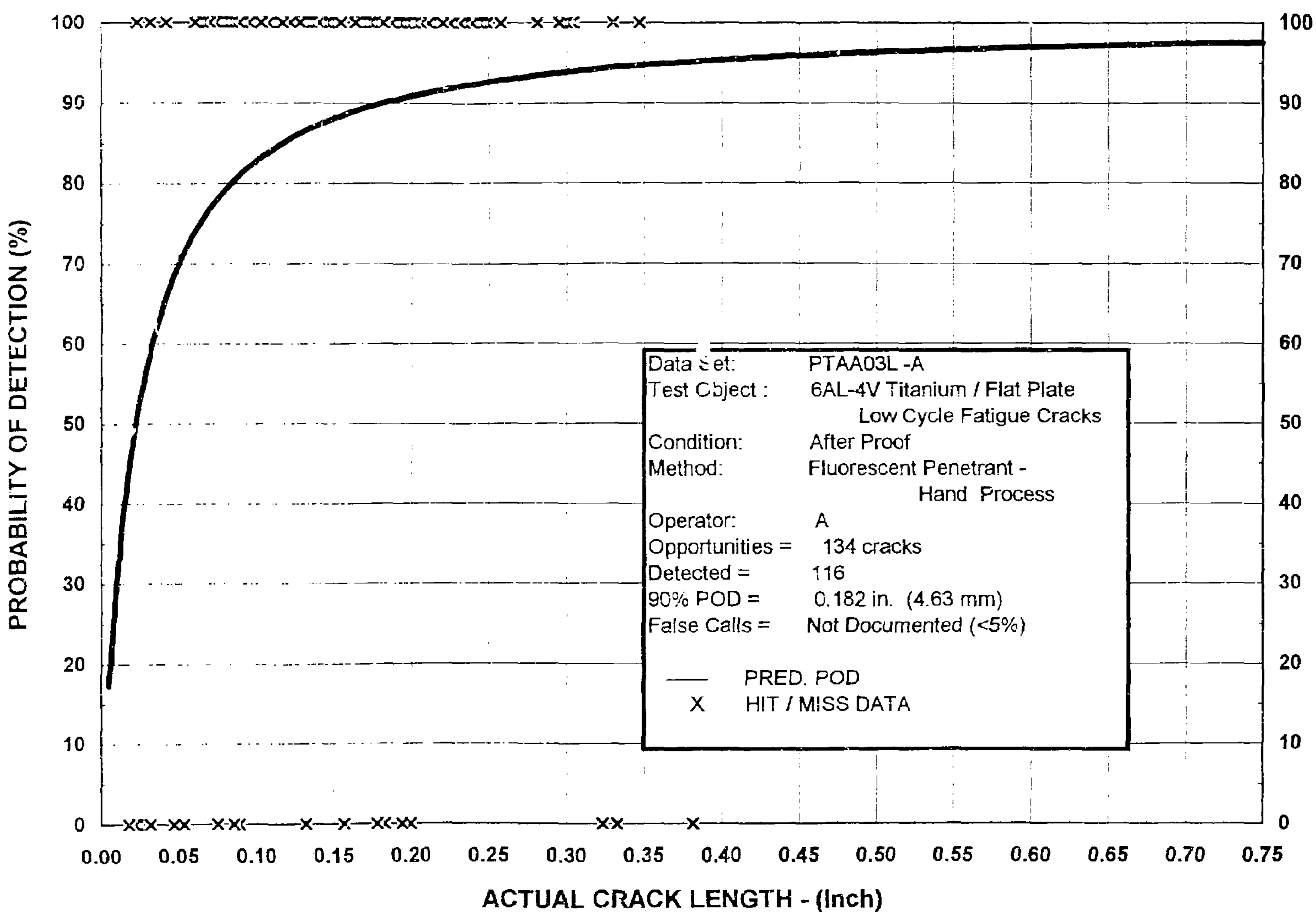


PTAA02L-C

AFTER ETCH - OPERATOR C

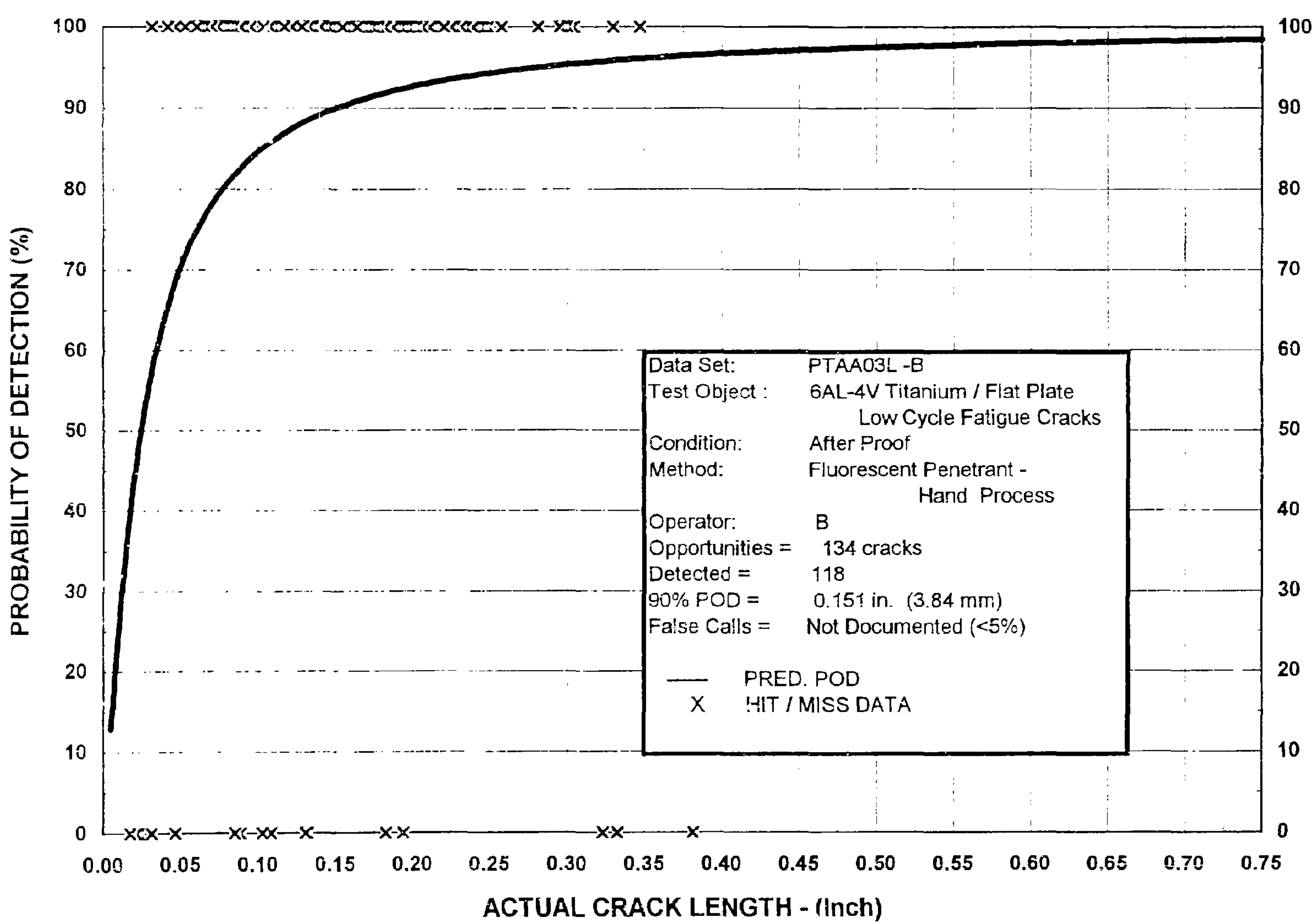
PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS

6/95



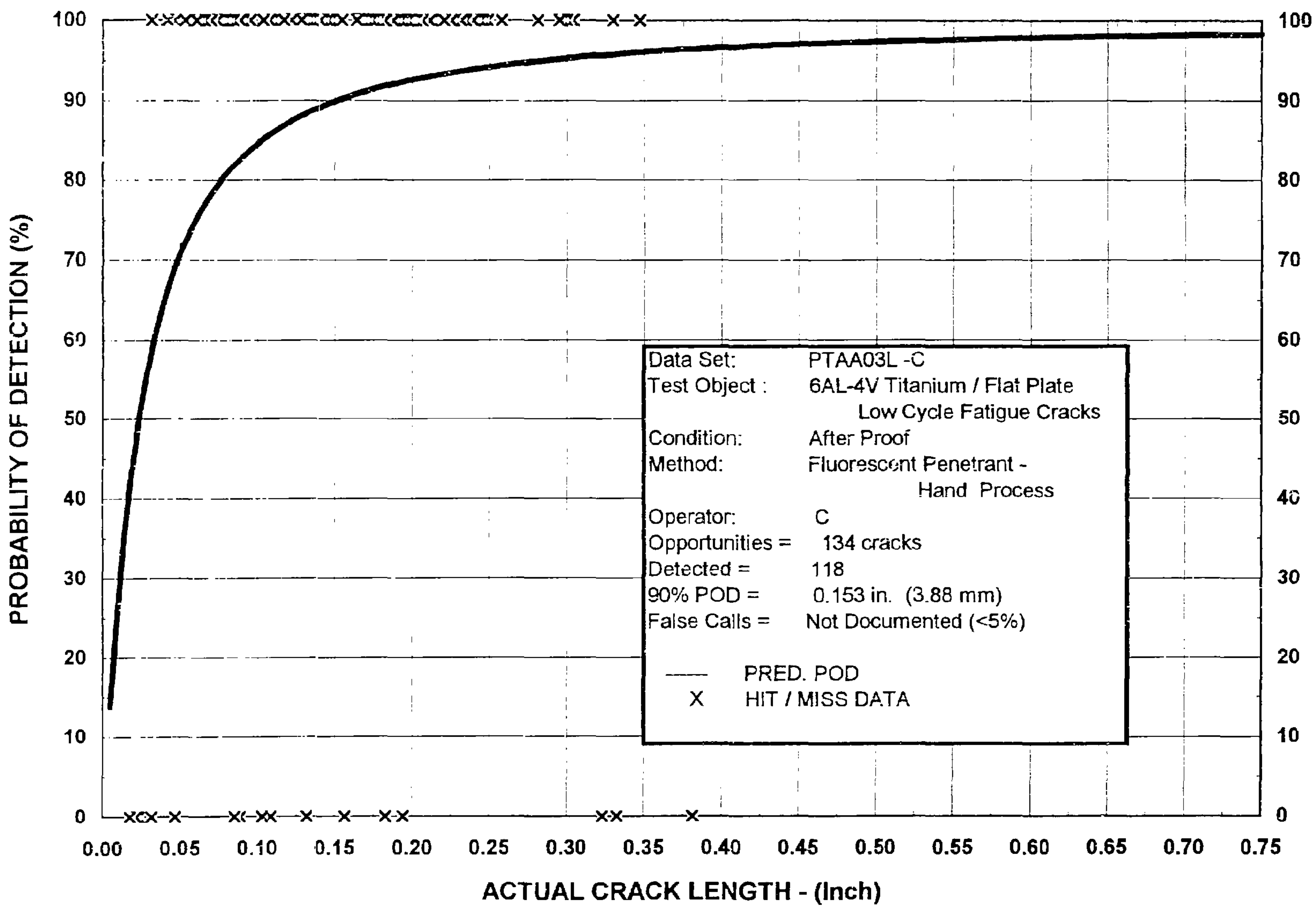
PTAA03L-A
AFTER PROOF - OPERATOR A

PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS
6/95



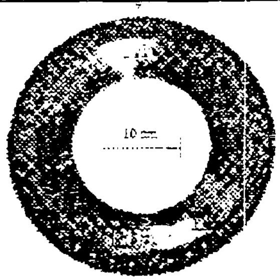
PTAA03L-B
AFTER PROOF - OPERATOR B

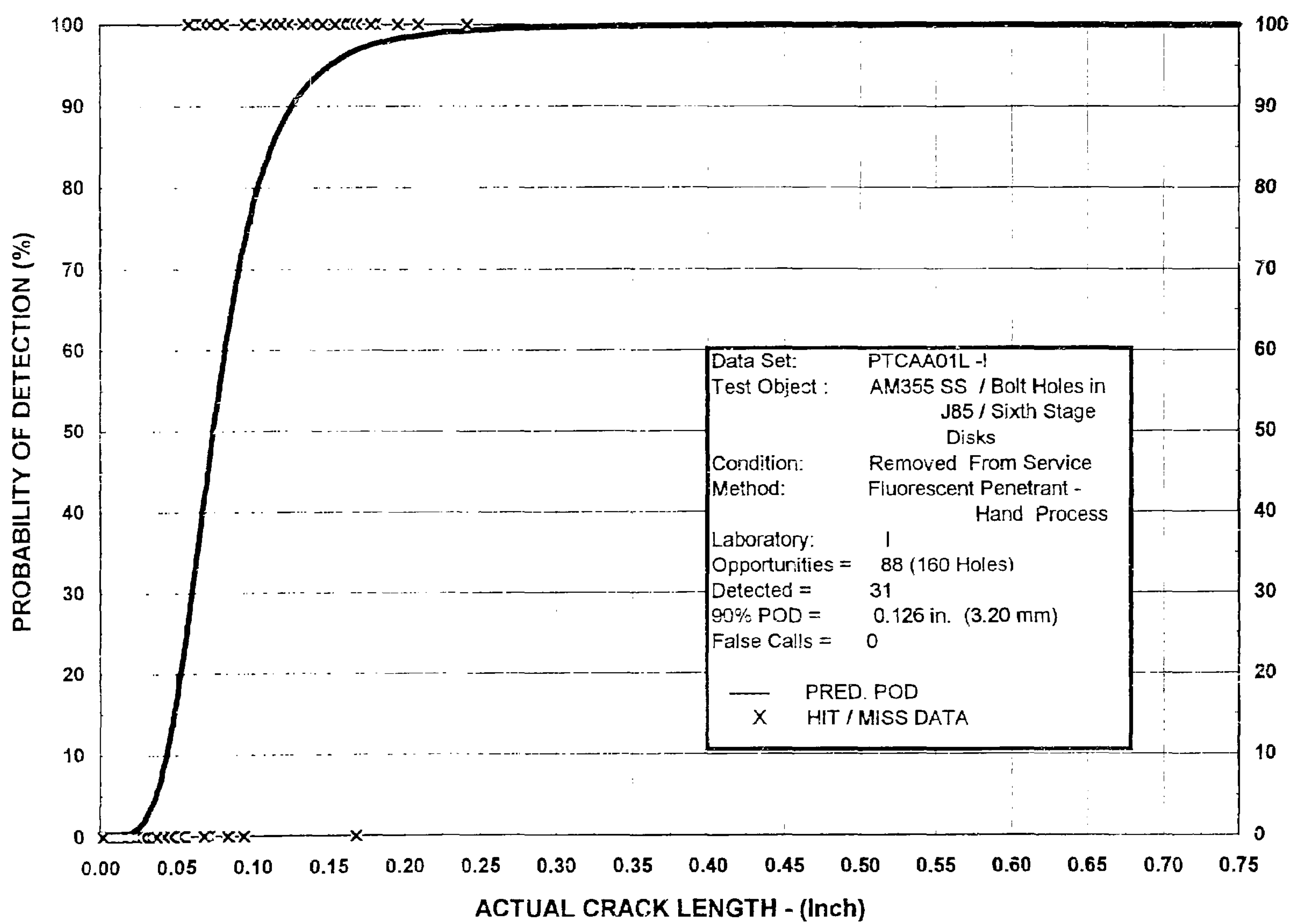
PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS
6/95



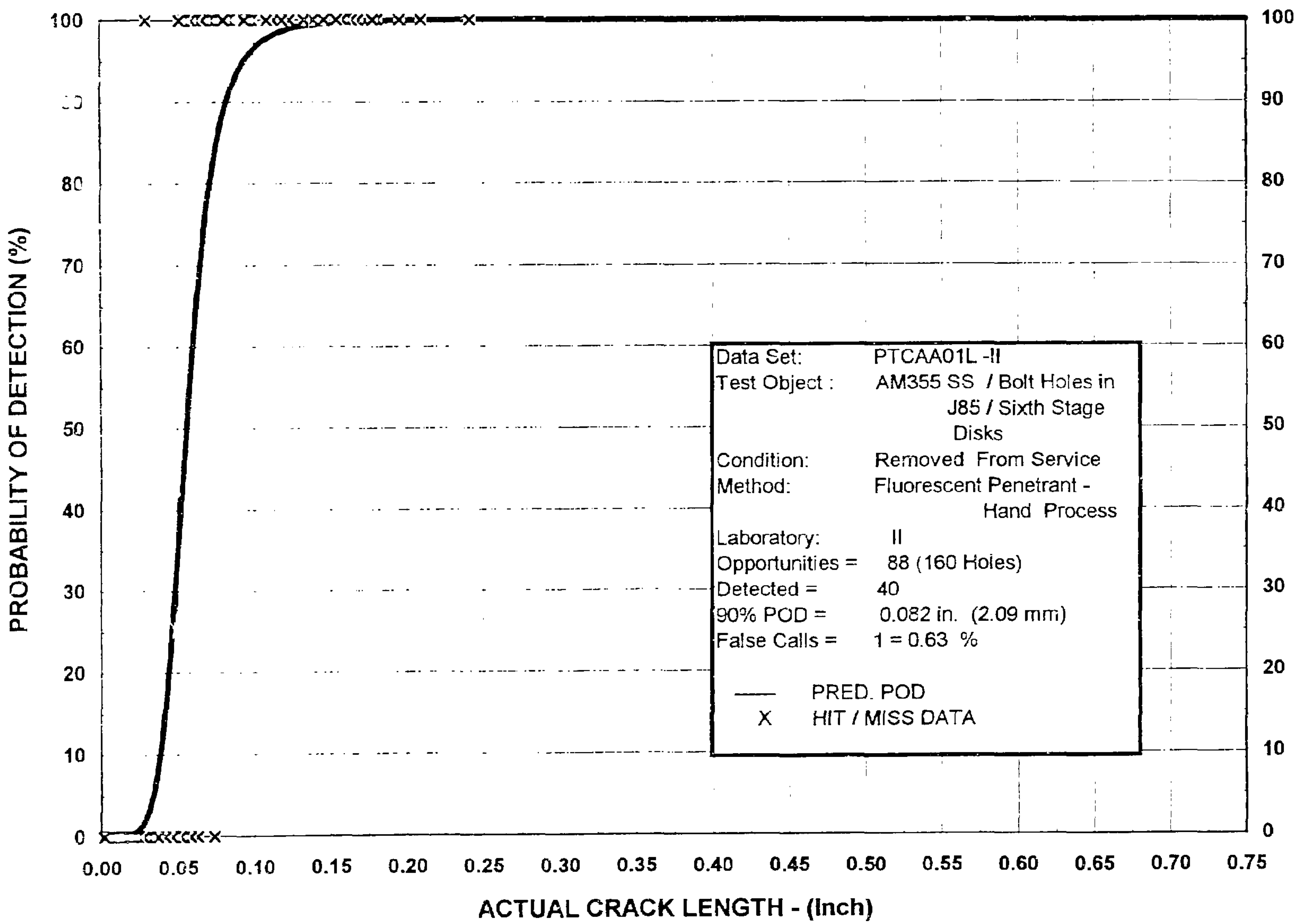
PTAA03L-C
AFTER PROOF - OPERATOR C

PT - 03 (2) PENETRANT INSPECTION OF TITANIUM PANELS
6/95

PT- 04 (4)	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Bolt holes in J85 / Sixth stage compressor disks; 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Fluorescent penetrant, manual inspection
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	PTCAA01L -I; PTCAA01L -II; PTCAA01L -III; AND PTCAA01L -IV
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	I: 160 holes/88 cracks ; II: 160 holes/88 cracks; III: 160 holes/88 cracks; IV: 160 holes/88 cracks
DETECTED:	ORG I: 31; ORG II. 40; ORG III: 52; ORG IV: 34
FALSE CALLS:	ORG I: 0; ORG II: 1 = 0.63% ; ORG III: 5 = 3.12 %; ORG IV: 1 = 0.63%
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG I: 0.126 in. (3.20mm)
	ORG II: 0.082 in. (2.09mm)
	ORG III: 0.098 in. (2.49mm)
	ORG IV: 0.135 in. (3.48mm)

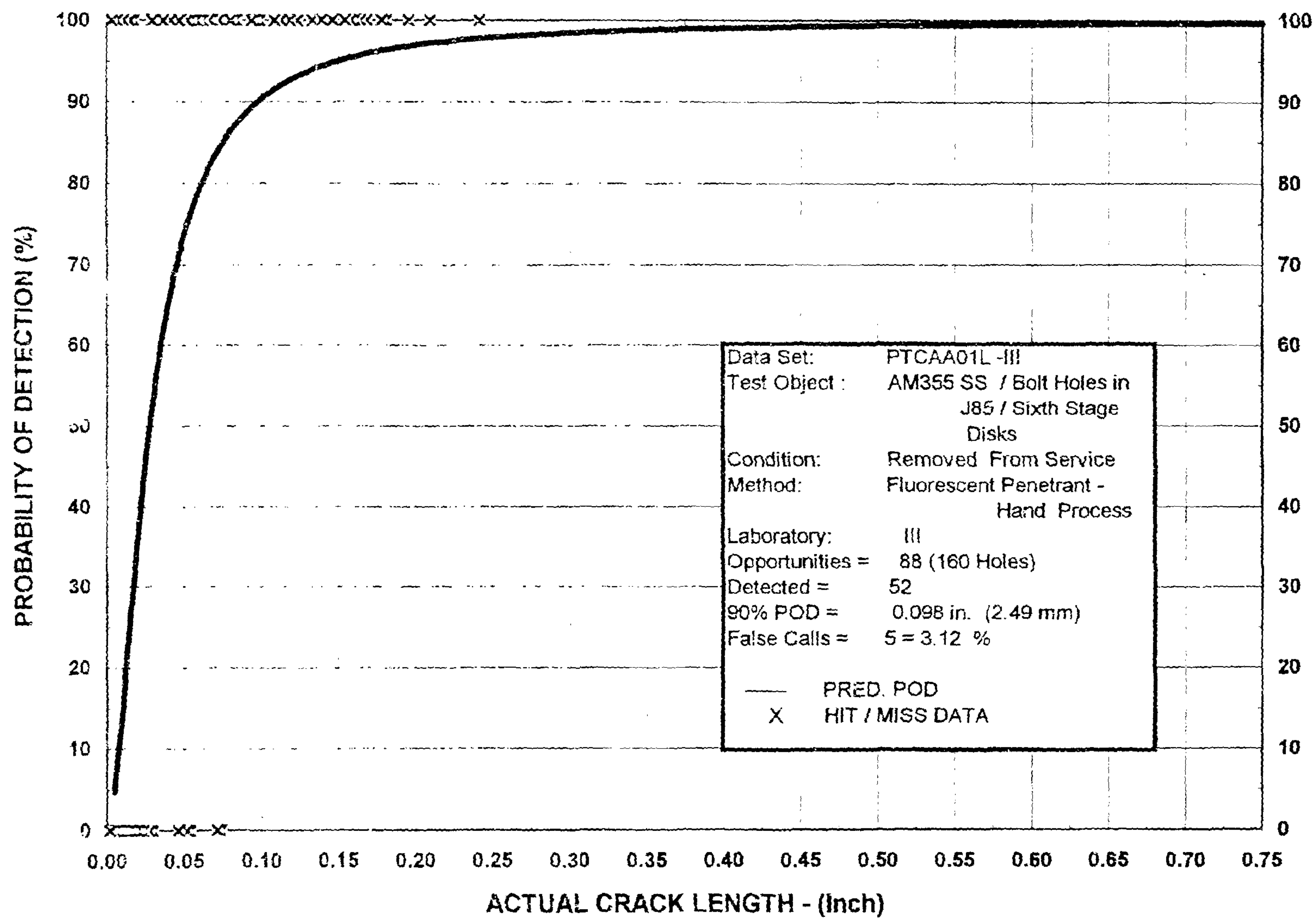


PTCAA01L-I
(ORG. I)



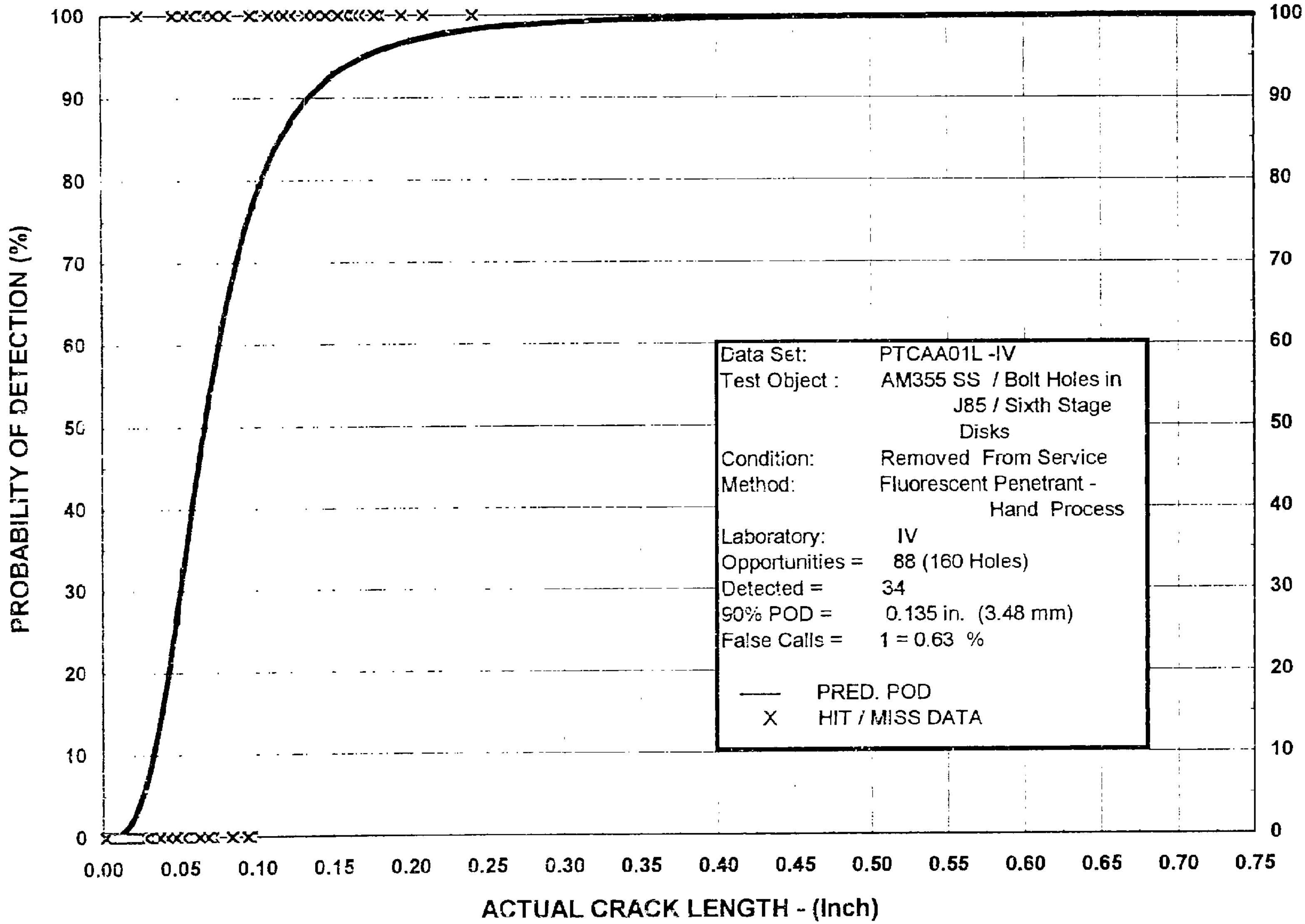
PT - 04 (4)
6/95

PTCAA01L-II
(ORG. II)



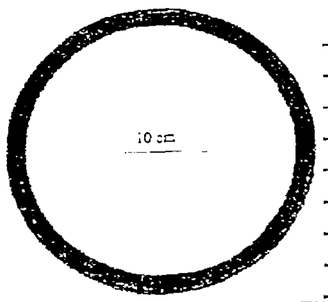
ET 04 (4)
8/95

PTCAA01L-III
(ORG. III)

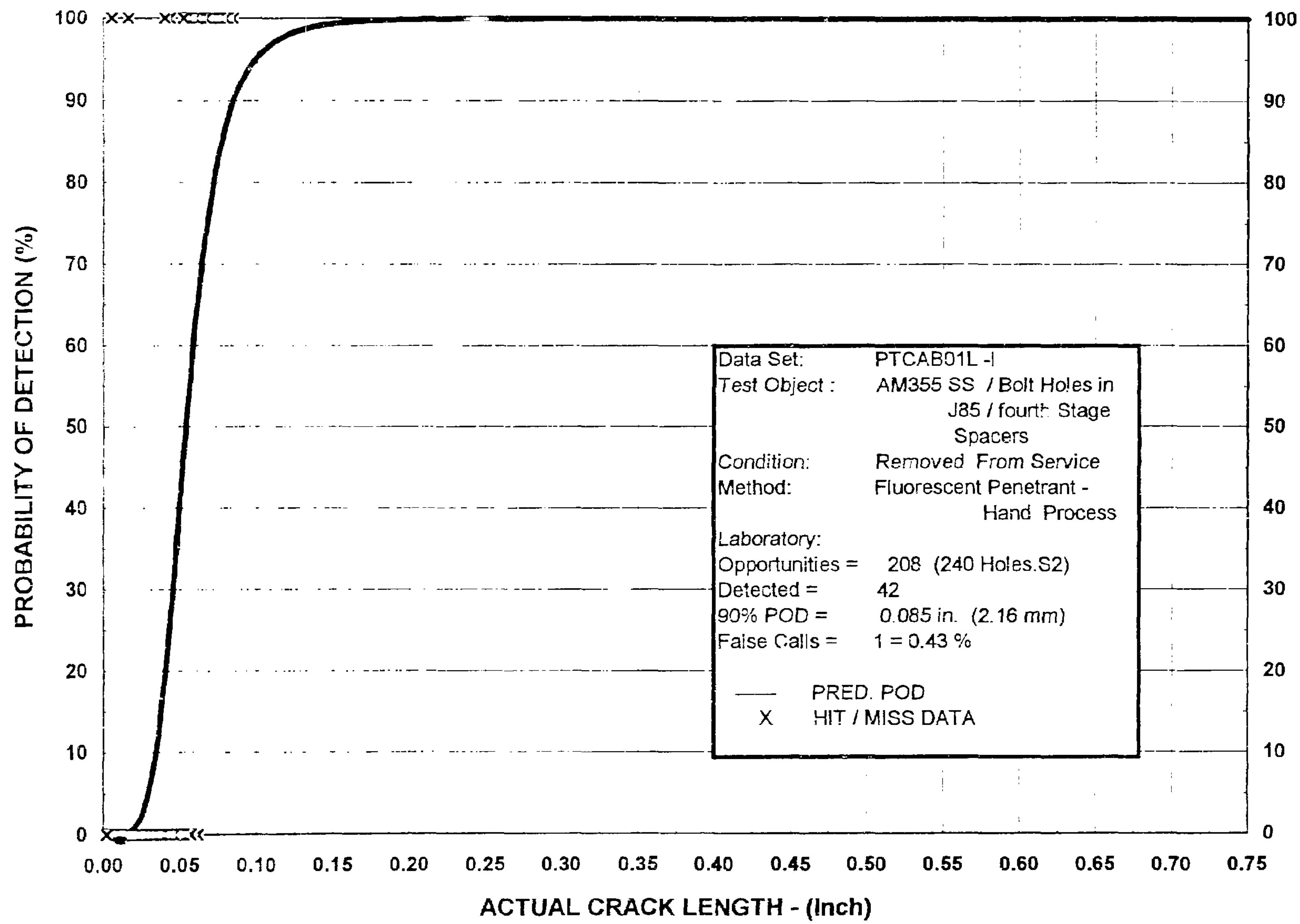


PT - 04 (4)
6/95

PTCAA01L-IV
(ORG. IV)

PT - 05 (4)	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Bolt holes in J85 / Fourth stage spacers; 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Fluorescent penetrant, manual inspection
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	PTCAB01L-I , PTCAB01L-II, PTCAB01L-IV, and PTCAB01L-VI
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	I: 240 holes,S2/ 208 cracks ;II: 240 holes,S1,S2/ 216 cracks; IV: 240 holes,S1/ 208 cracks; VI: 160 holes,S2/ 57 cracks
DETECTED:	I: 42 cracks ;II: 62 cracks; IV: 45 cracks; VI: 4 cracks
FALSE CALLS:	I: 1 = 0.43% ;II: 1 = 0.2%; IV: 0; VI: 0
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG I: 0.085 in. (2.16 mm)
	ORG II: 0.082 in. (2.08 mm)
	ORG IV: 0.090 in. (2.28 mm)
	ORG VI: 0.093 in. (2.35 mm)

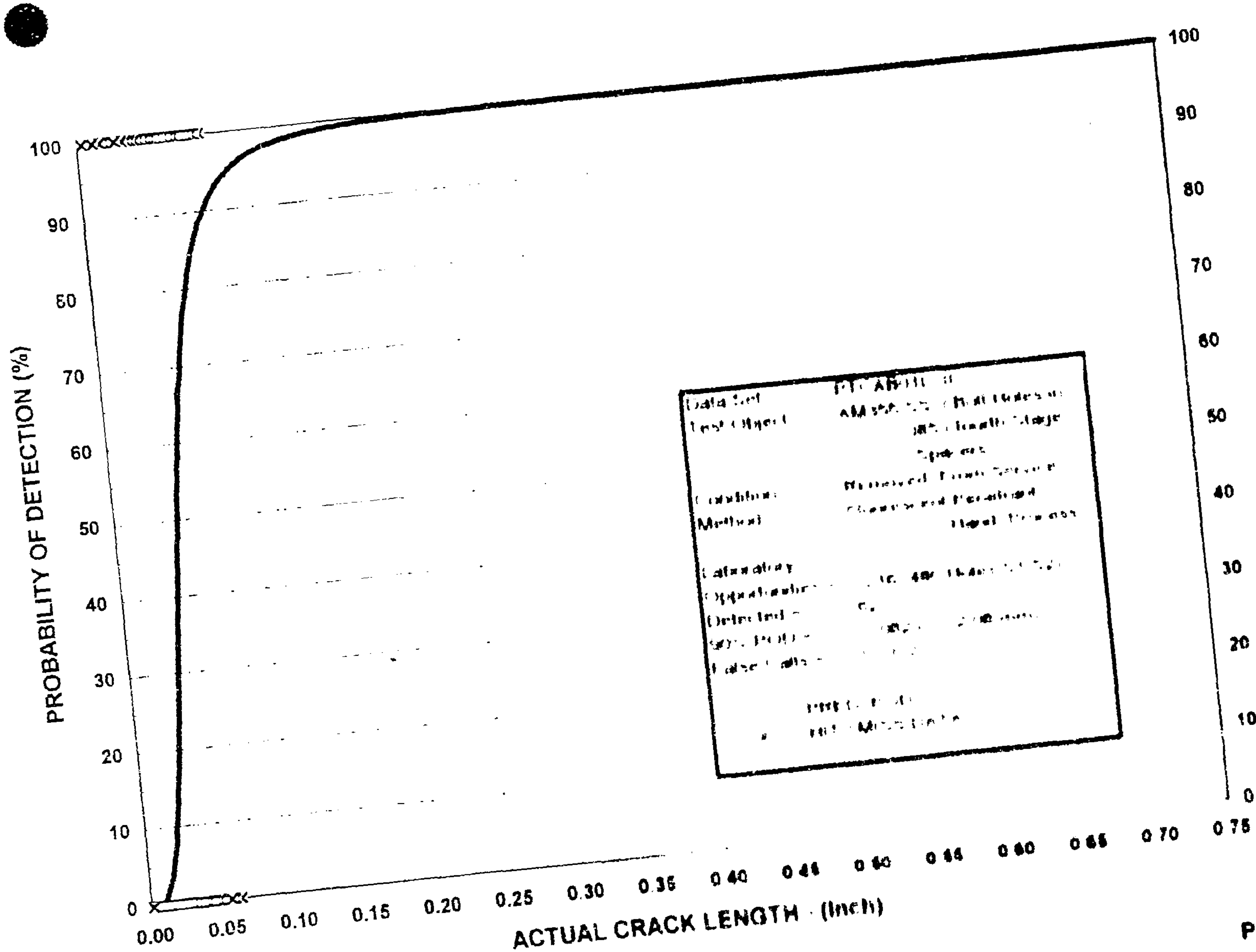
FLUORESCENT PENETRANT
GAS TURBINE ENGINE SPACERS



PT - 05 (4) - GAS TURBINE ENGINE SPACERS

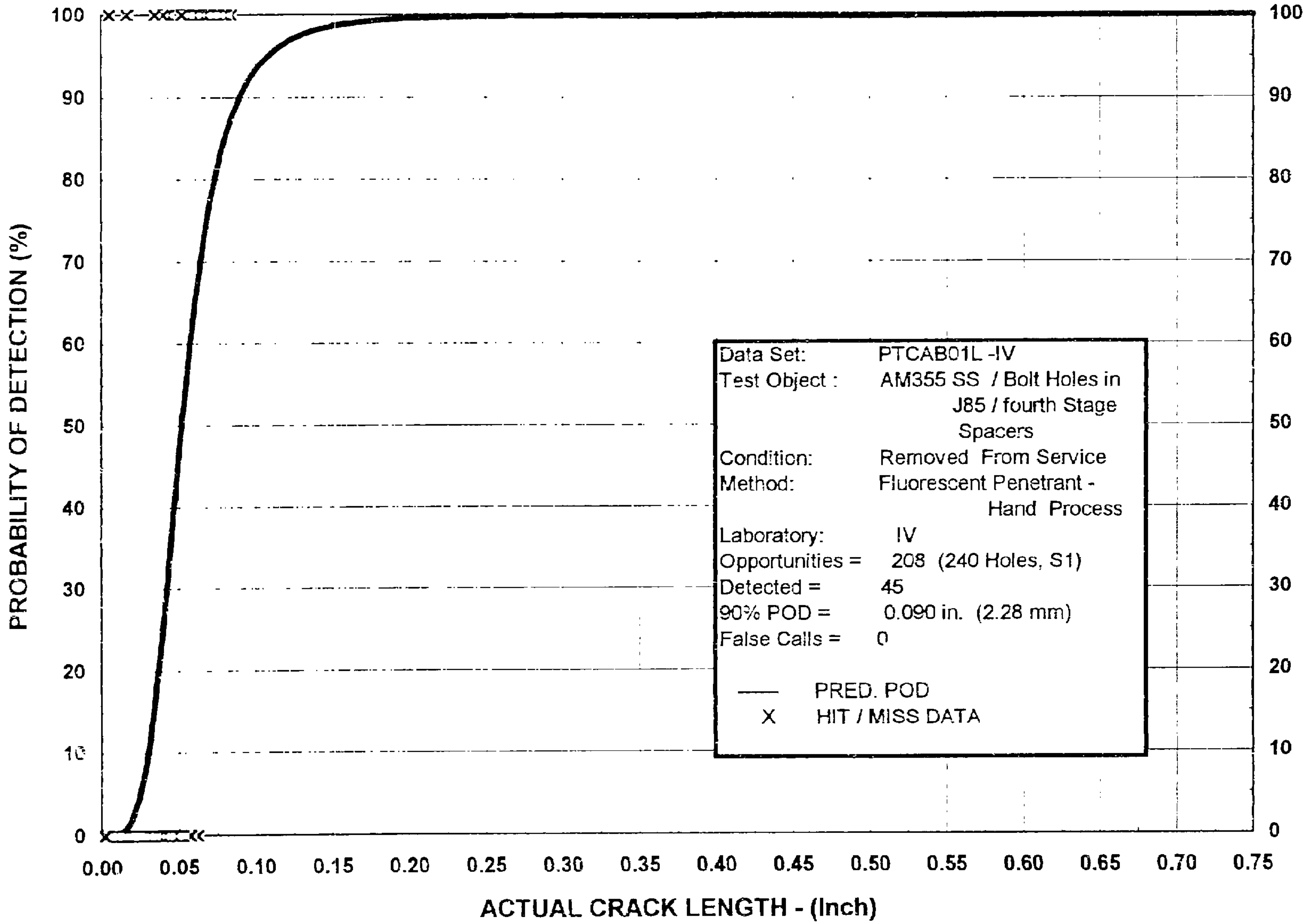
6/95

PTCAB01L-I
(ORG. I)



PTCAB01L-II
(ORG. II)

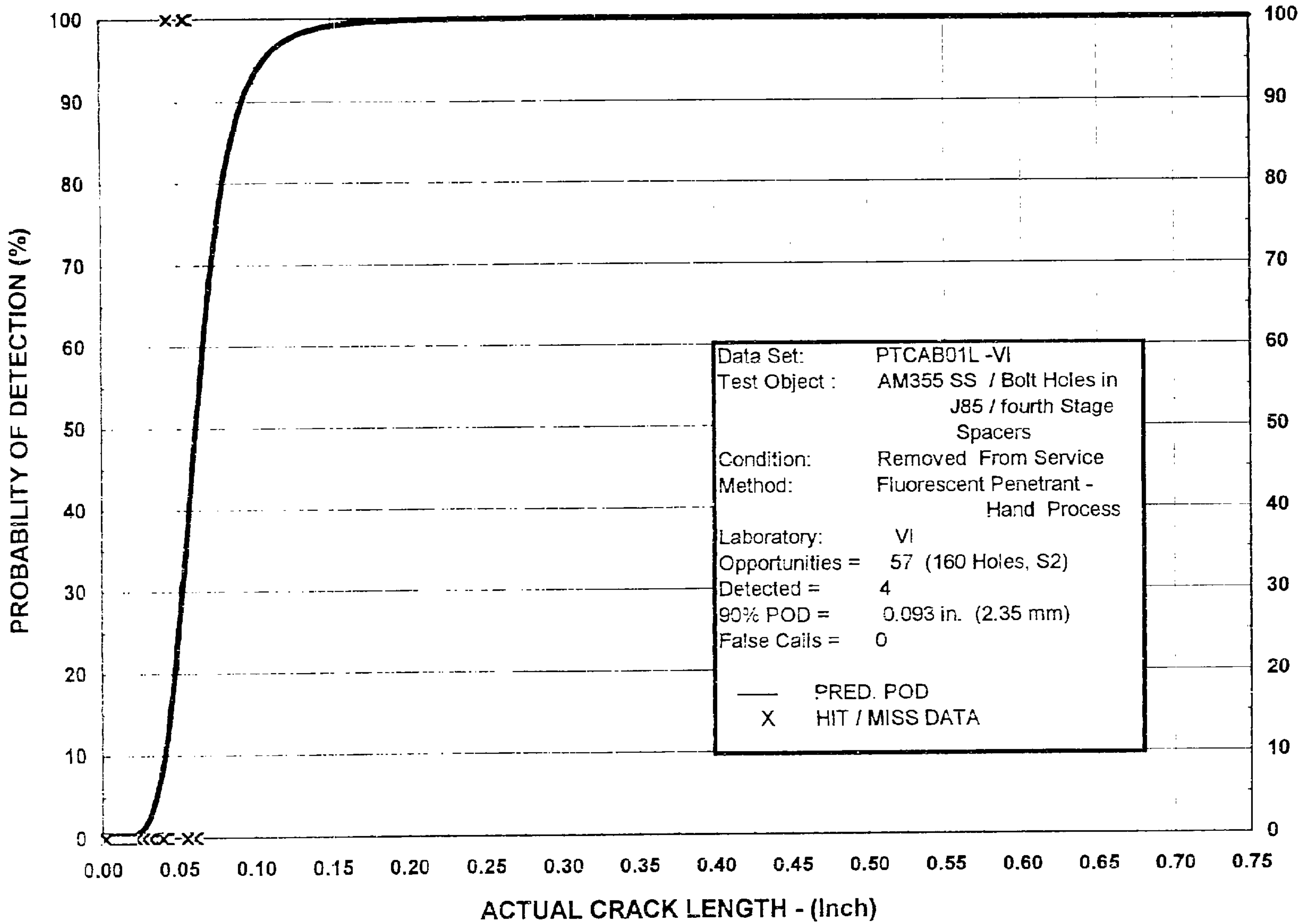
PT - 05 (4) - GAS TURBINE ENGINE SPACERS
6/95



PT - 05 (4) - GAS TURBINE ENGINE SPACERS

6/95

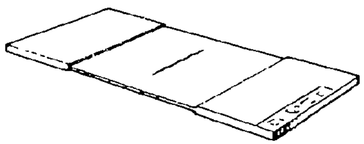
PTCAB01L-IV
(ORG. IV)



PT - 05 (4) - GAS TURBINE ENGINE SPACERS
6/95

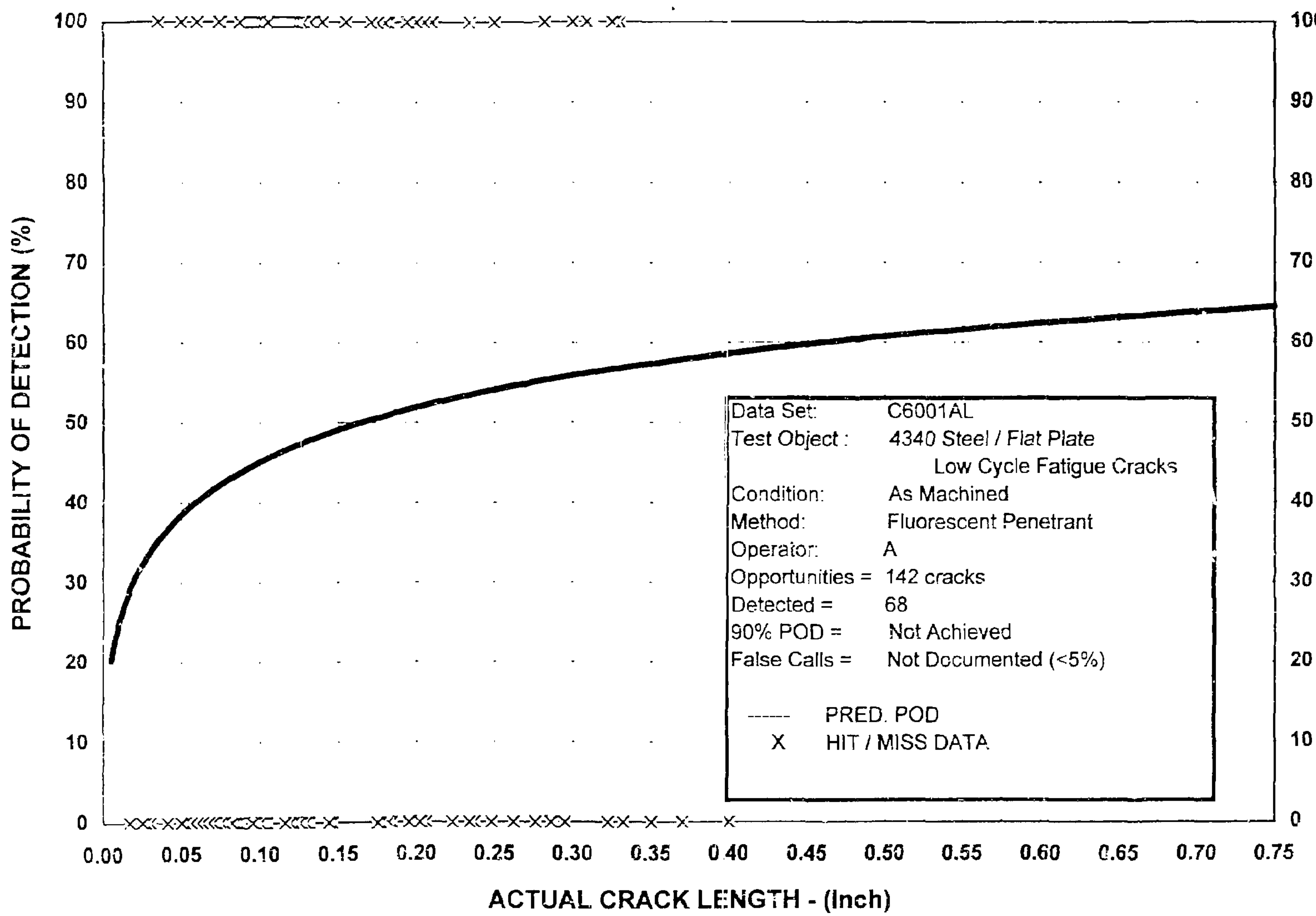
PTCAB01L-VI
(ORG. VI)

C6000(2)L	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetant - Uresco P149
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Fluorescent Penetant - URESCO P149. Solvent Removable, Spray Developer
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	C6001, "As Machined", C6002, "After Etch", C6003, "After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	C6001-A,B,C; C6002-A,B,C; C6003-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	176 Cracks -Variation in the number inspected during each sequence C6001-A = 68/142, B=73/142, C= 74/142; C6002-A =129/142, B=137/142, C=137/142;
DETECTED:	C6003 - A= 134/176, B=144/176, C=154/176
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



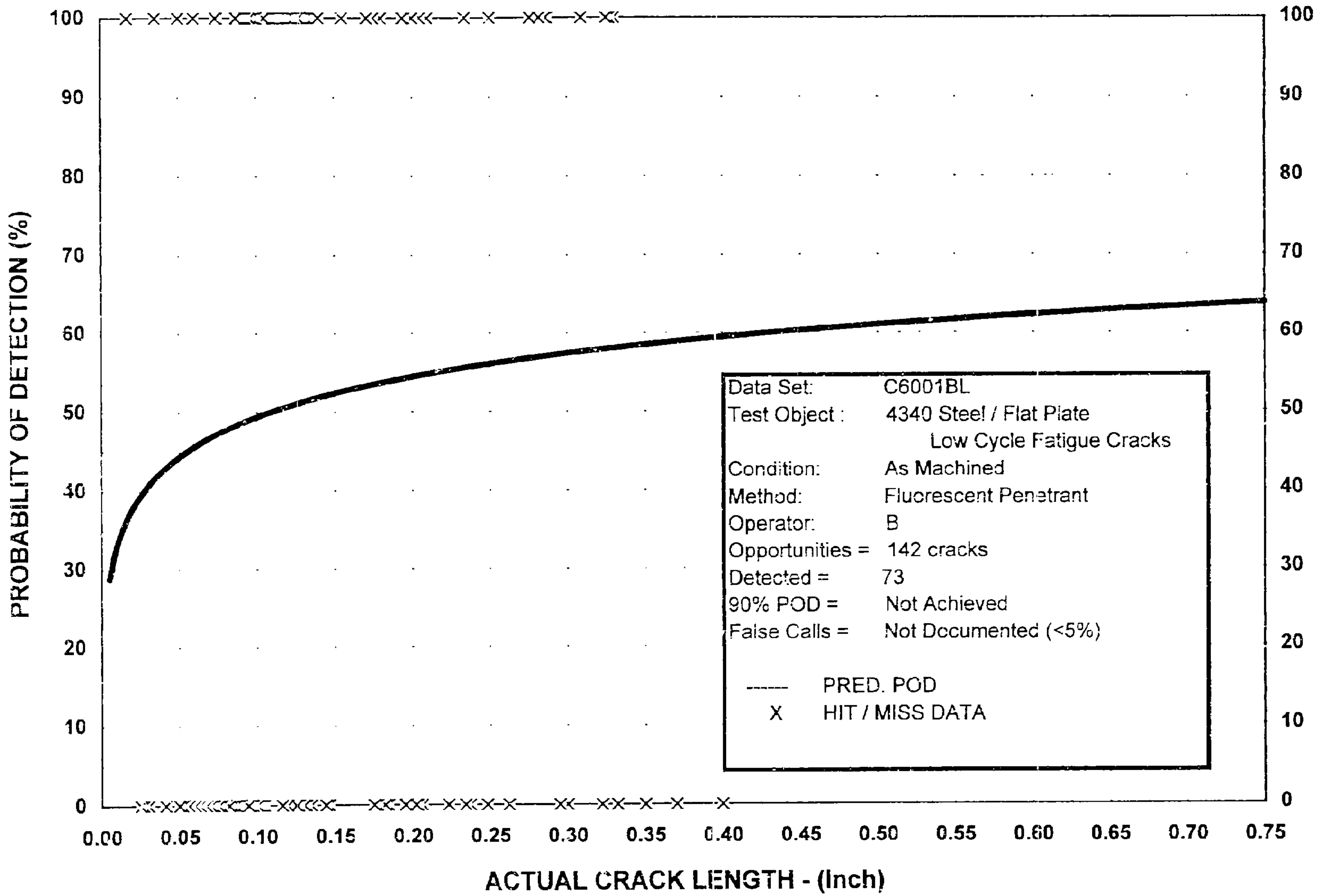
90% POD	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= Not Achieved	A= 0.099in. (2.51mm	A= 0.260in. (6.62mm)
	B= Not Achieved	B= 0.059in. (1.49mm)	B= 0.155in.(3.93mm)
	C= Not Achieved	C= 0.083in. (2.11mm)	C= 0.108in.(2.75mm)

FLUORESCENT PENTRANT
STEEL PANELS



C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS
9/96 - C6001AL

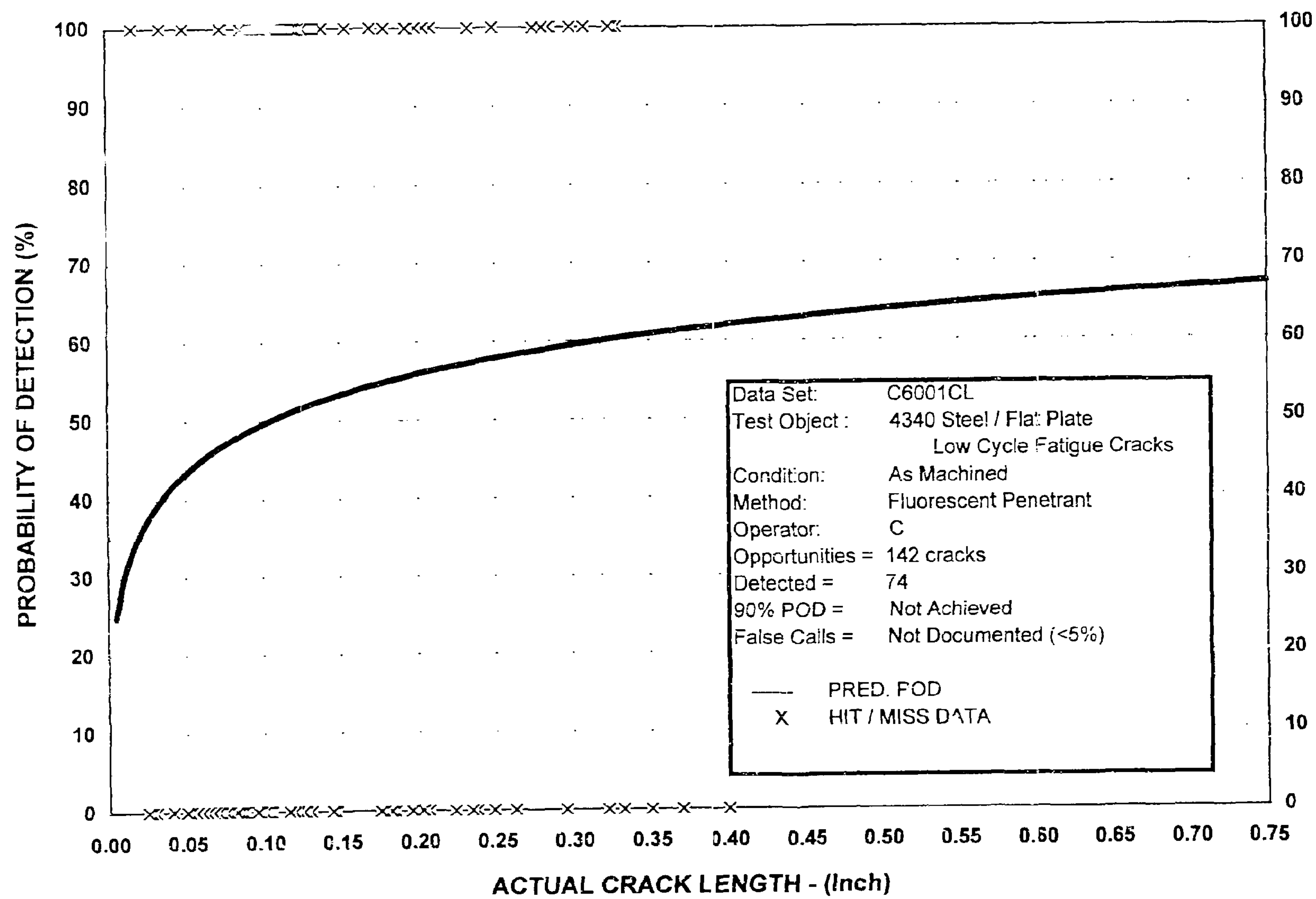
C6001AL
AS MACHINED - OPERATOR A



C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS

9/96 - C6001BL

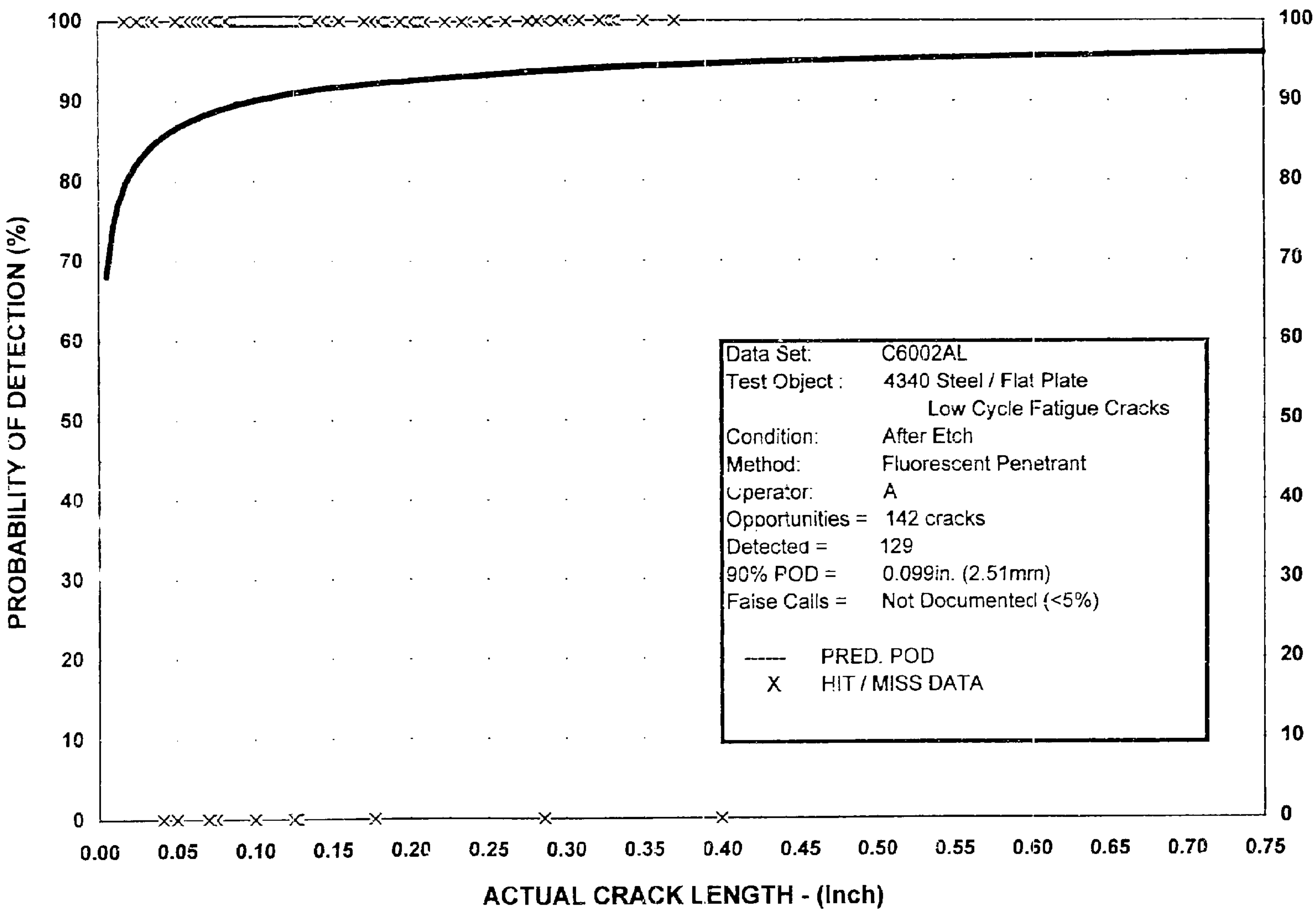
C6001BL
AS MACHINED - OPERATOR B



C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS

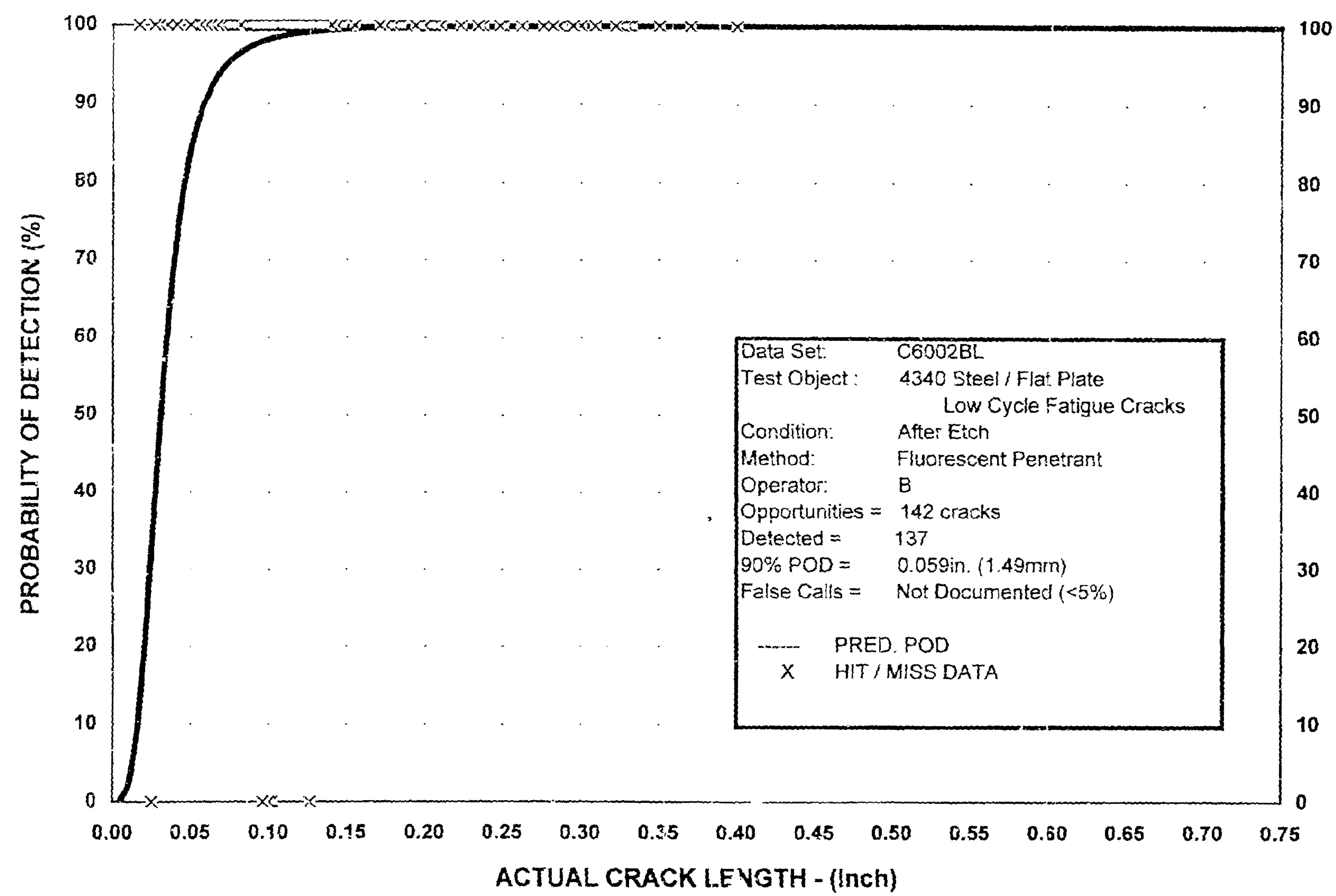
9/96 - C6001CL

C6001CL
AS MACHINED - OPERATOR C



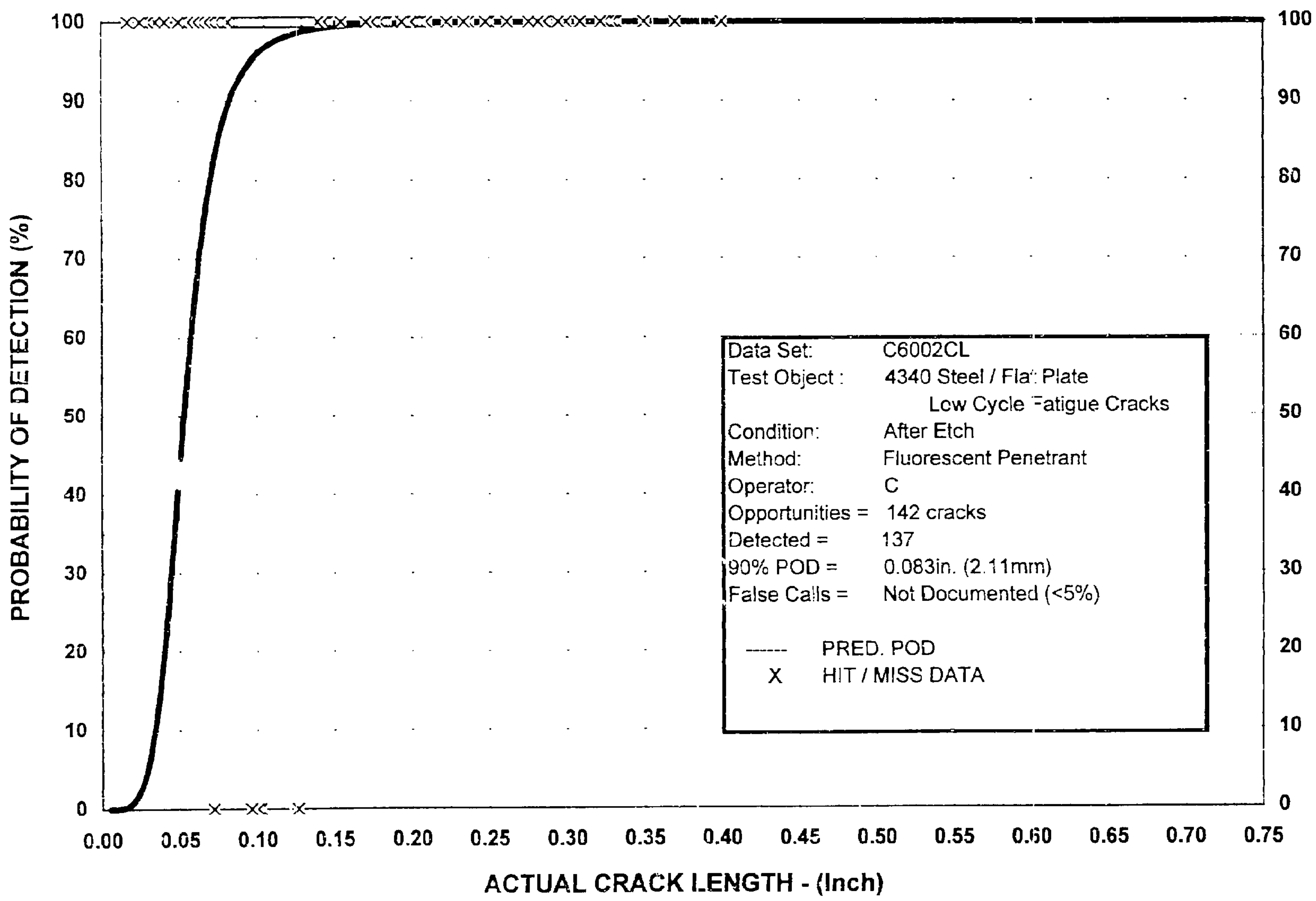
C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS
9/96 - C6002AL

C6002AL
AFTER ETCH OPERATOR A



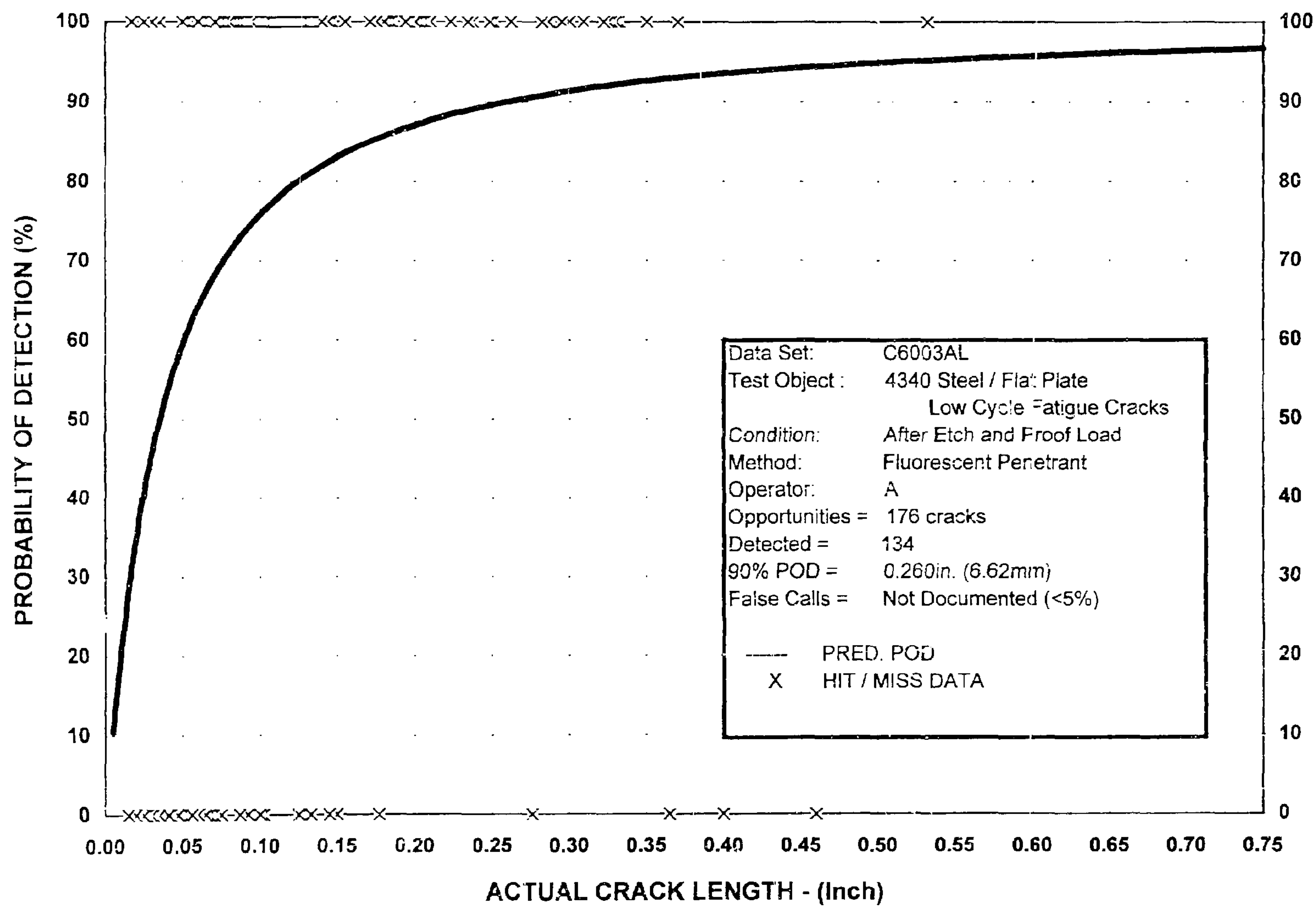
C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS
9/96 - C6002BL

C6002BL
AFTER ETCH OPERATOR B



C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS
9/96 - C6002CL

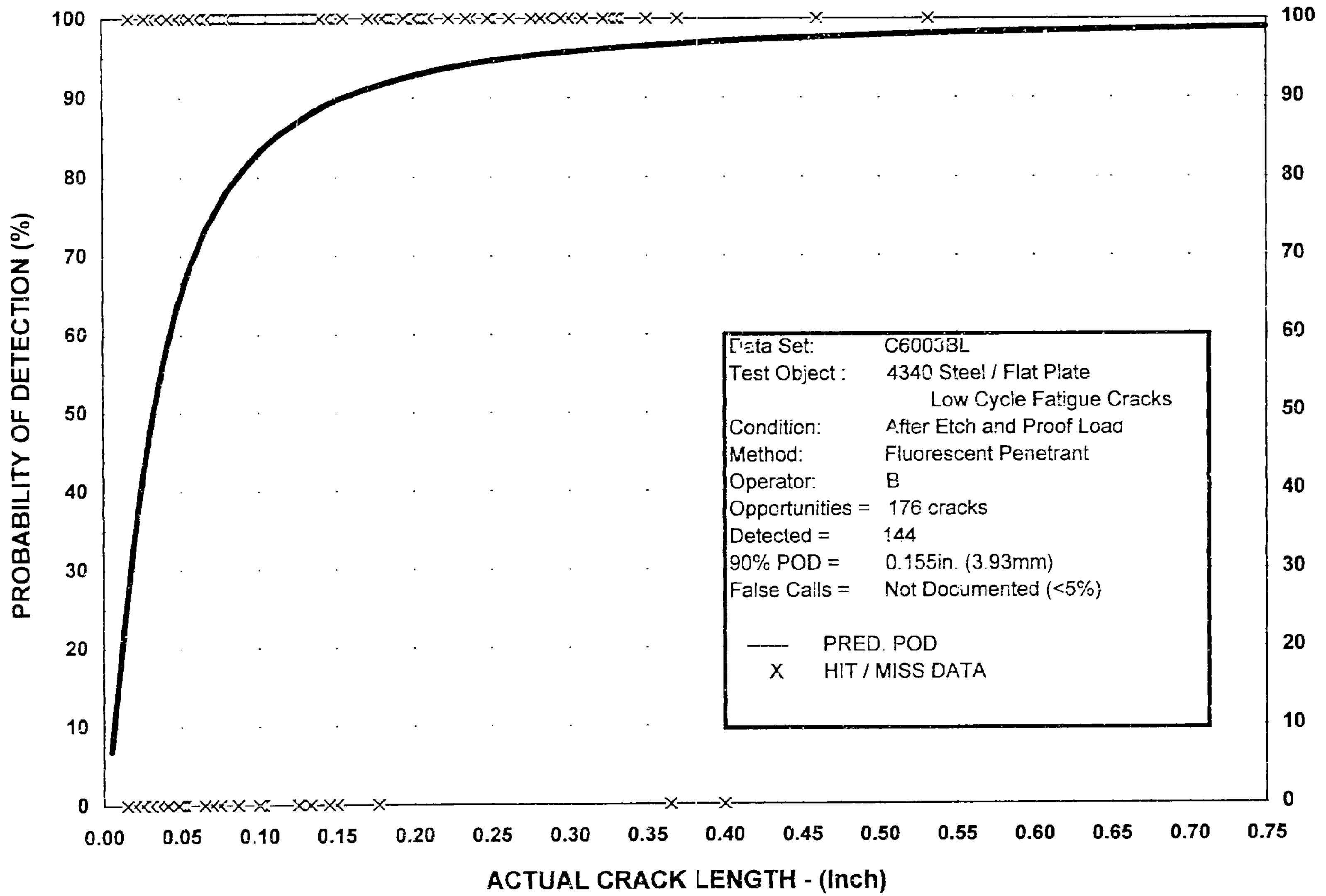
C6002CL
AFTER ETCH OPERATOR C



C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS

9/96 - C6003AL

C6003AL
AFTER ETCH AND PROOF LOAD - OPERATOR A

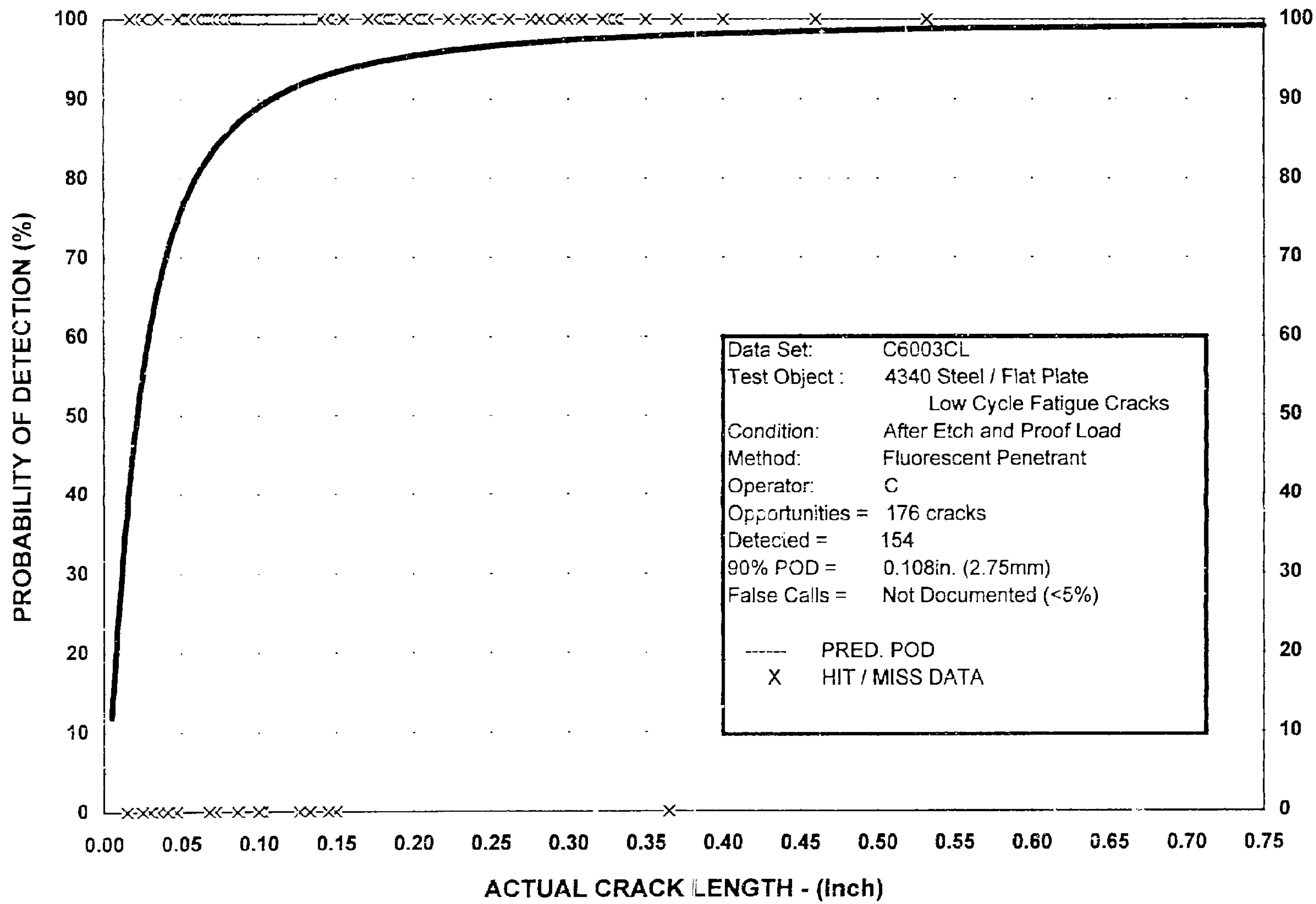


C6003BL

AFTER ETCH AND PROOF LOAD - OPERATOR B

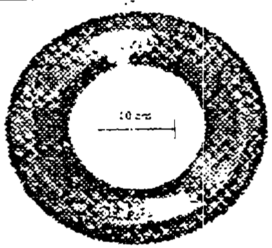
C6000(2) FLUORESCENT PENETRANT INSPECTION OF 4340 STEEL PANELS

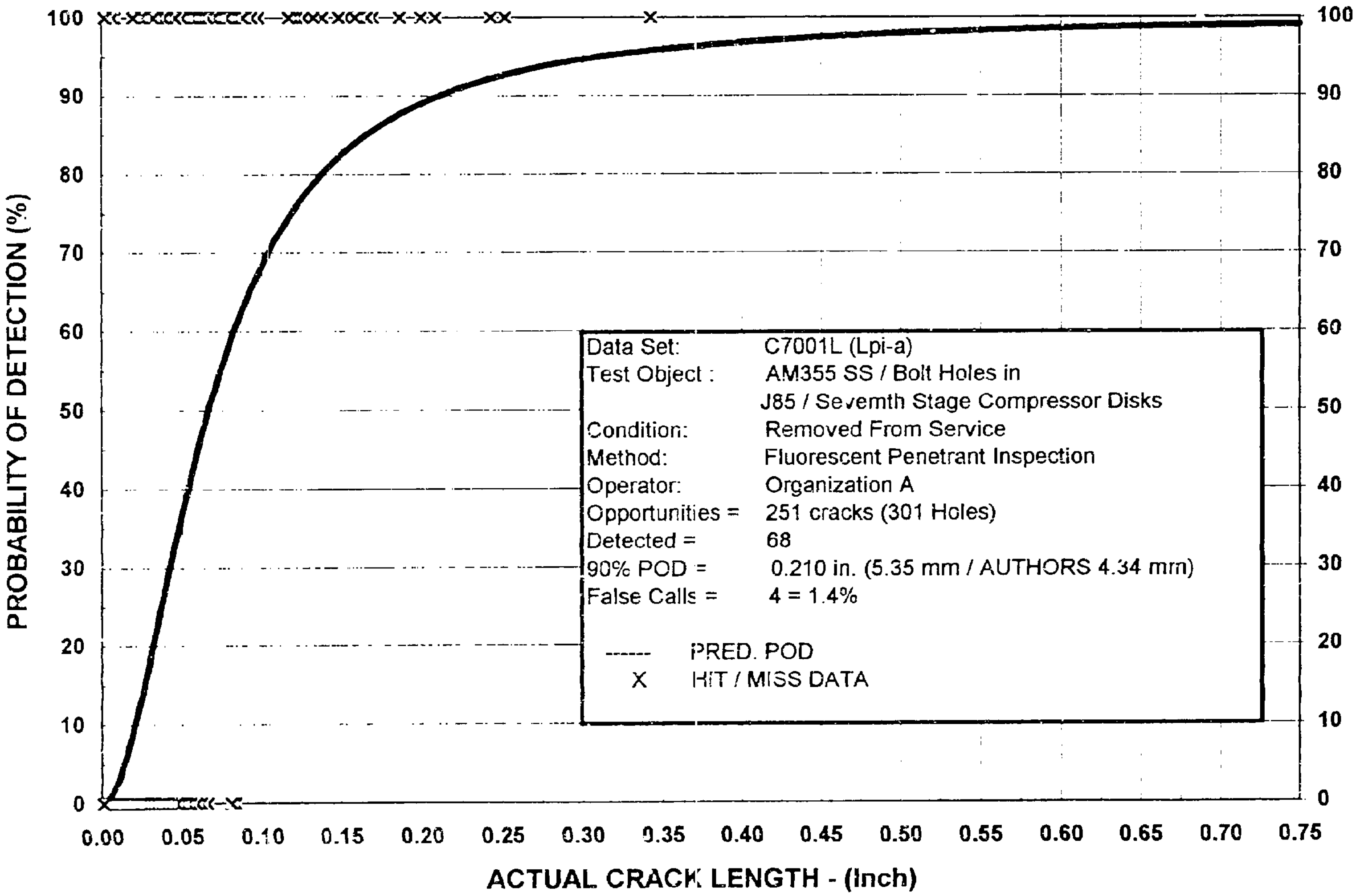
9/96 - C6003BL



C6003CL
AFTER ETCH AND PROOF LOAD - OPERATOR C

C6000(2) FLUORESCENT PENETRANT INSPECTION
OF 4340 STEEL PANELS
9/96 - C6003CL

C7000(7)L	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant
TEST OBJECT TYPE:	Bolt holes in J85 / Seventh stage compressor disks; 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Fluorescent Penetrant (Level II)
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual processing
DATA SET IDENTIFIERS:	C7001L, C7002L; and C7003L
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	381 Holes / 320 cracks
DETECTED:	C7001L - 68, C7002L -33; and C7003L - 46
FALSE CALLS:	C7001L - 4, C7002L - 1; and C7003L - 0
REFERENCE:	LTR-ST-2055, D.S. Forsyth and A. Fahr, **The Sensitivity and Reliability of NDI Techniques for Gas Turbine Components Inspection and Life Prediction**,
DATE:	August, 1996.
WORK SPONSOR:	Department of National Defence, DAS Eng 6-2.
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	The maximum likelihood method of curve fitting used in this databook differs slightly from the algorithm used by the authors. The authors calculated values are shown for reference.
	Maximum differences are shown for those data sets with the greatest variance. The authors noted difficulties fitting such data to the model.
	90% POD ORG A: 0.210 in. (5.35 mm / Authors - 4.34 mm)
	ORG C: 0.349 in. (8.85 mm / Authors - 8.89mm)
	ORG D: 0.297 in. (7.56 mm / Authors - 9.02 mm)

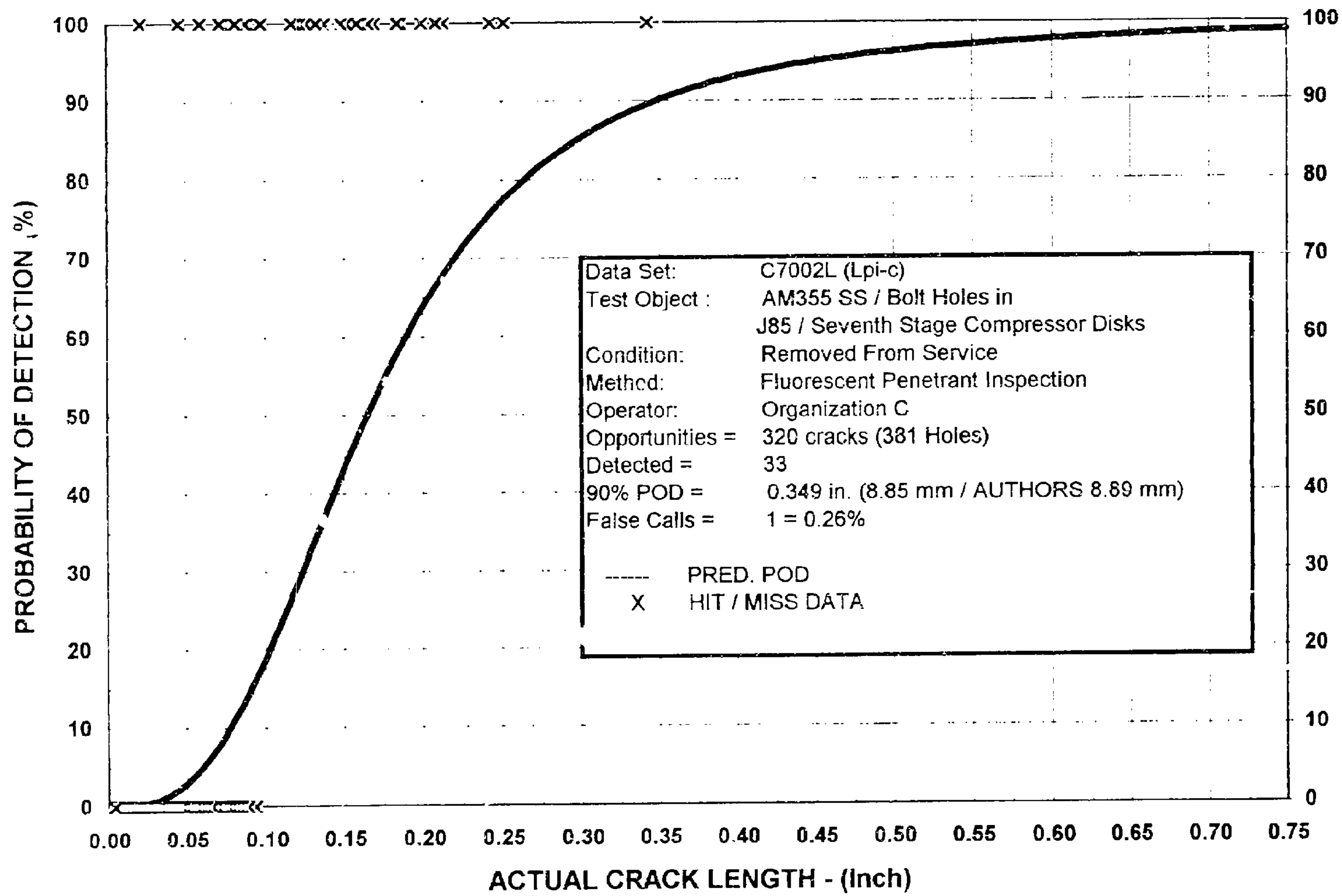


C7001L Service Induced Cracks
ORGANIZATION A

C7000(7) FLUORESCENT PENETRANT INSPECTION OF BOLT HOLES

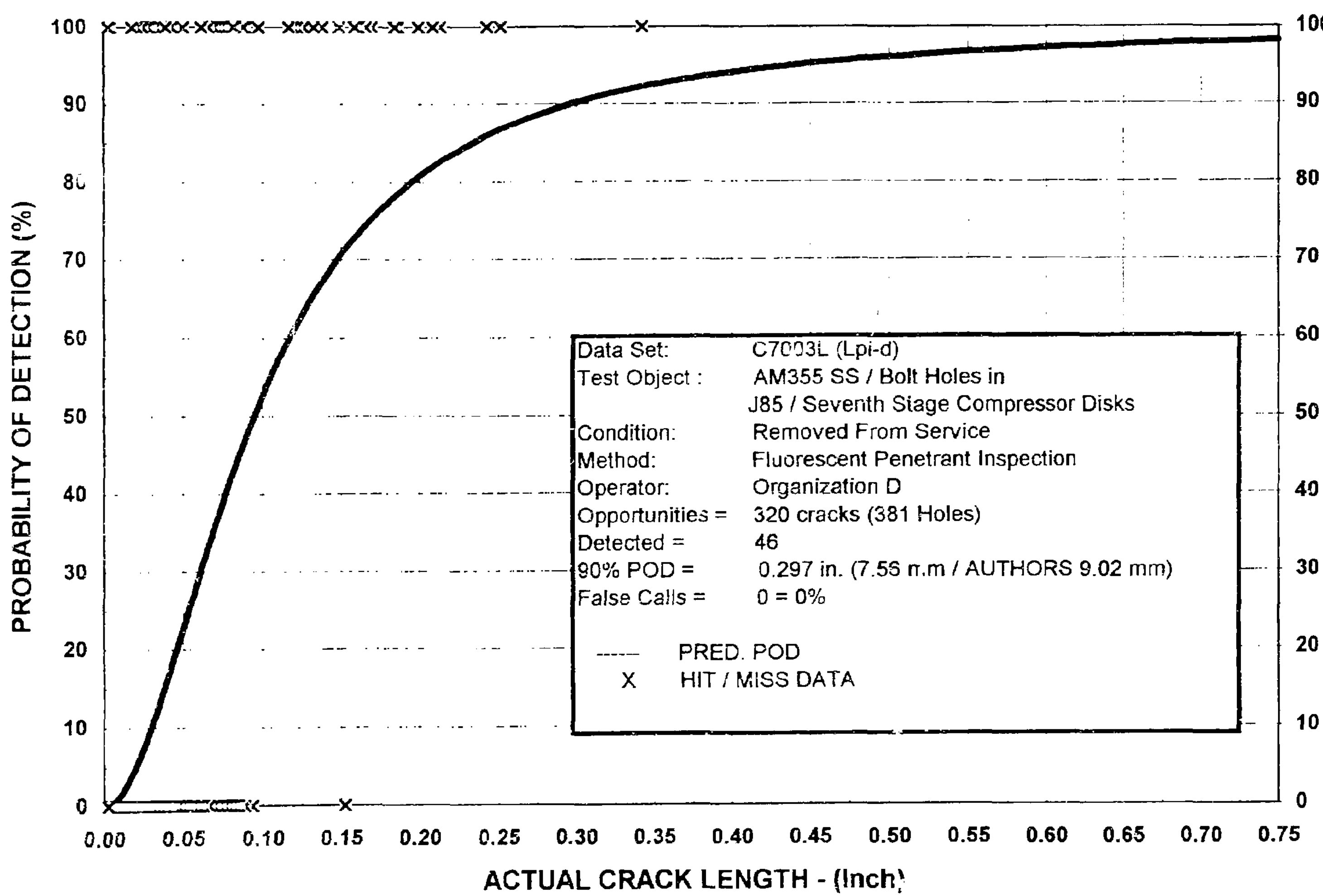
9/96 - C7001L

C7002L Service Induced Cracks
ORGANIZATION C



C7000(7) FLUORESCENT PENETRANT INSPECTION OF BOLT HOLES

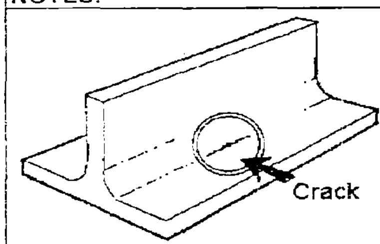
9/96 - C7002L



C7003L Service Induced Cracks
ORGANIZATION D

C7000(7) FLUORESCENT PENETRANT INSPECTION OF BOLT HOLES

9/96 - C7003L

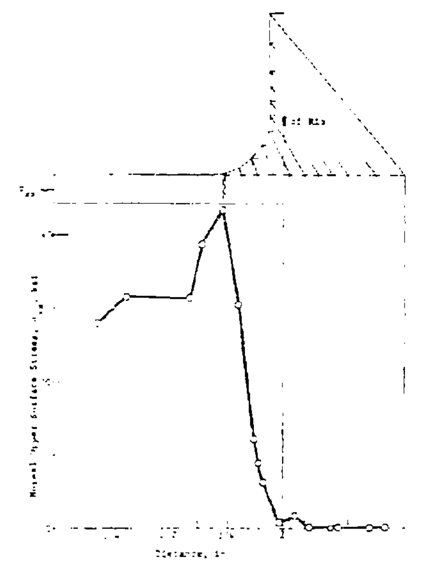
C8000(3)L,D	**DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS**
METHOD:	Fluorescent Penetrant Inspection
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (C8001 and C8002); Stringers Riveted to a Flat Plate (C8003)
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	Base Plate- 0.250 inch nominal / Webs - 0.250 inch nominal
TEST OBJECT CONDITION:	C8001,"As Machined"; C8002,"After Etch"; C8003, Stringers cut from panel and riveted to a flat plate.
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	C8001(3)L,D; C8002(3)L,D; C8003(3)L,D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	417 Cracks
DETECTED:	C8001(3)L/D = 318; C8002(3)L/D = 344 ; C8003(3)L/D =322 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	146 flaws were induced in 46 panels (both sides of the web). Four blank panels; included:Total of 50panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS MACHINED" "AFTER ETCH" "RIVETED CONFIGURATION"
	A= 0.440 IN. A= 0.395 in. A= 0.404 IN.
	90% POD Depth - "AS MACHINED" "AFTER ETCH" "RIVETED CONFIGURATION"
	A= 0.074 in. A= 0.079 in. A= 0.095 in.
Test Specimen Descriptions on the following page!	

C8000(3)L,D
6/97 -C8000(3)L,D

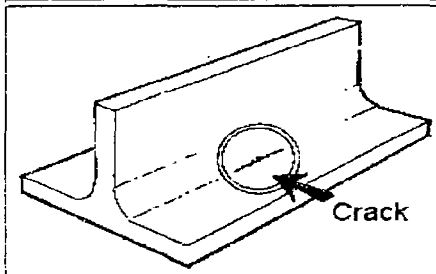
FLUORESCENT PENETRANT INSPECTION OF AIRCRAFT STRINGER SHAPES

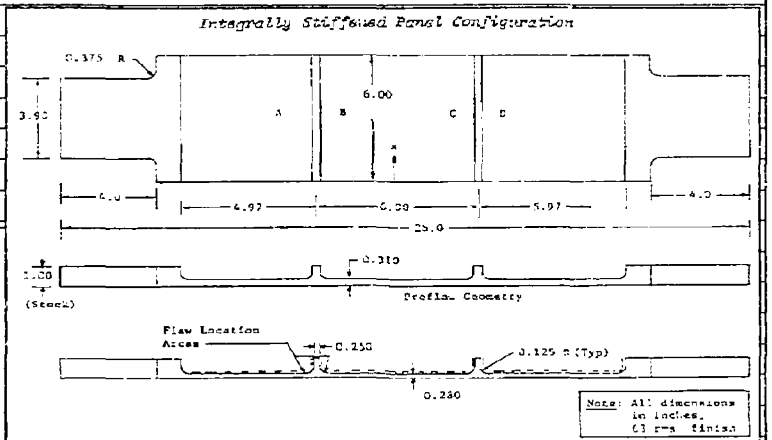
C8000(3)L,D	DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS
METHOD:	Fluorescent Penetrant Inspection
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (C8001 and C8002); Stringers Riveted to a Flat Plate (C8003)
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer

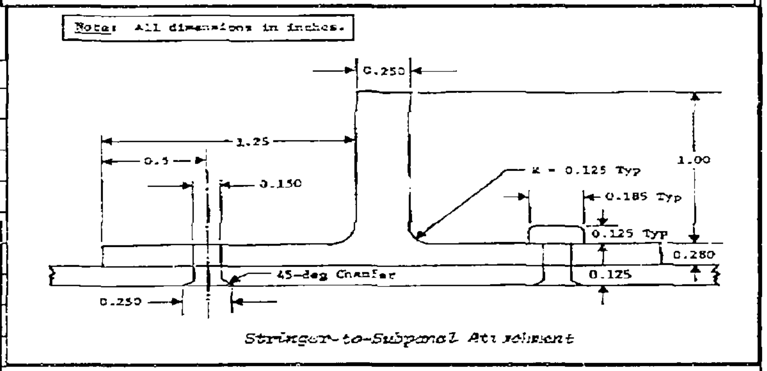
TEST SPECIMEN DESCRIPTORS

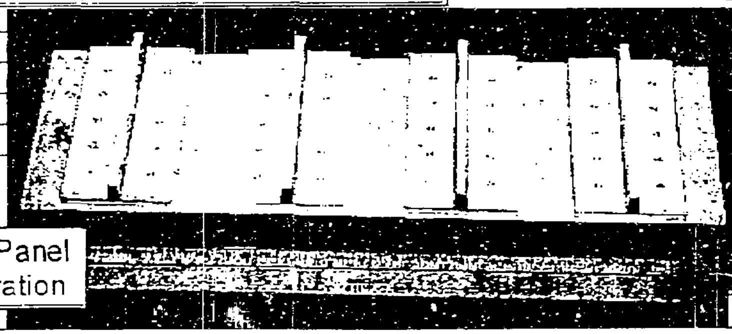


Anticipated Surface Stress Distribution for and axial load (panel plane)





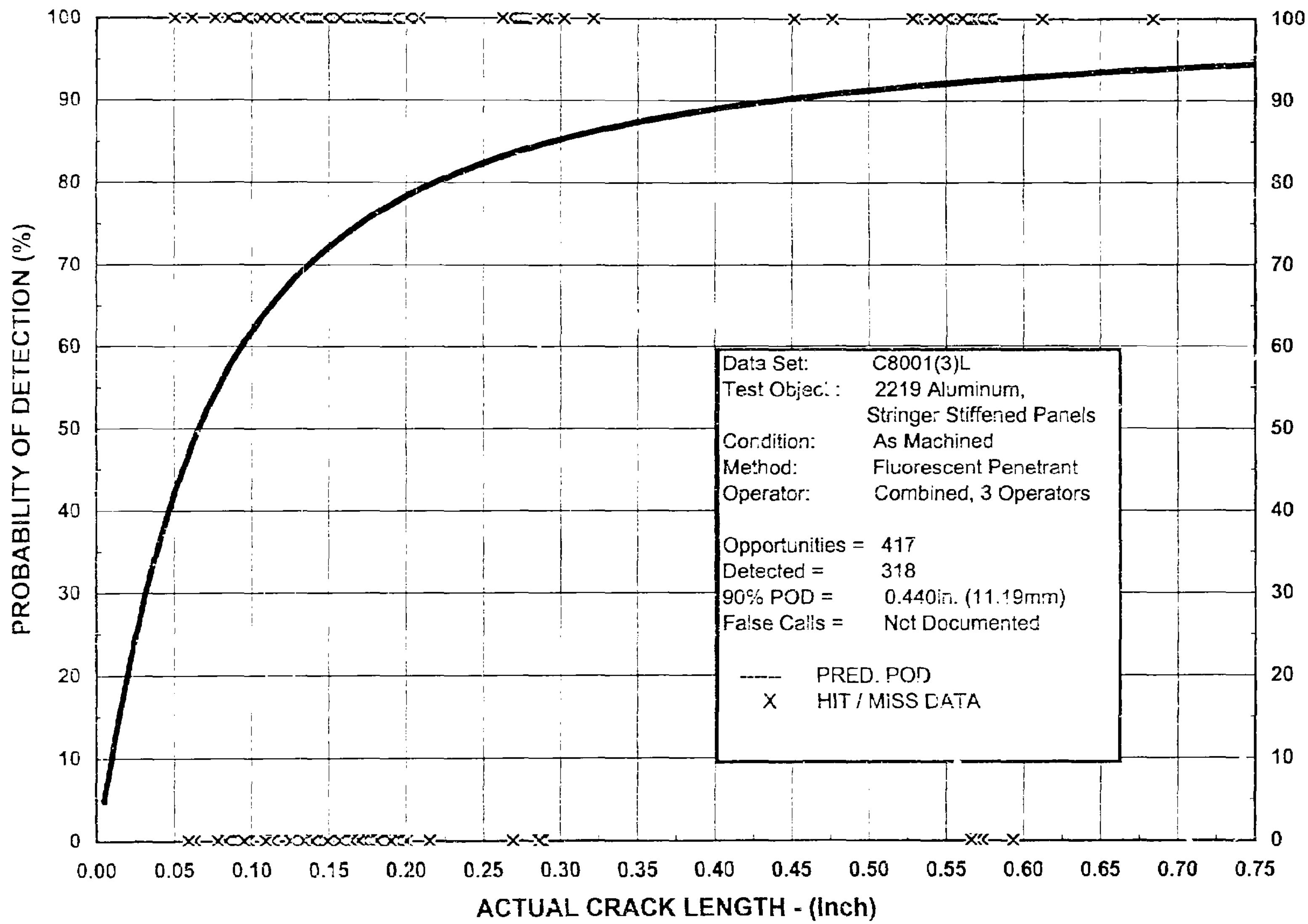




Riveted Panel Configuration

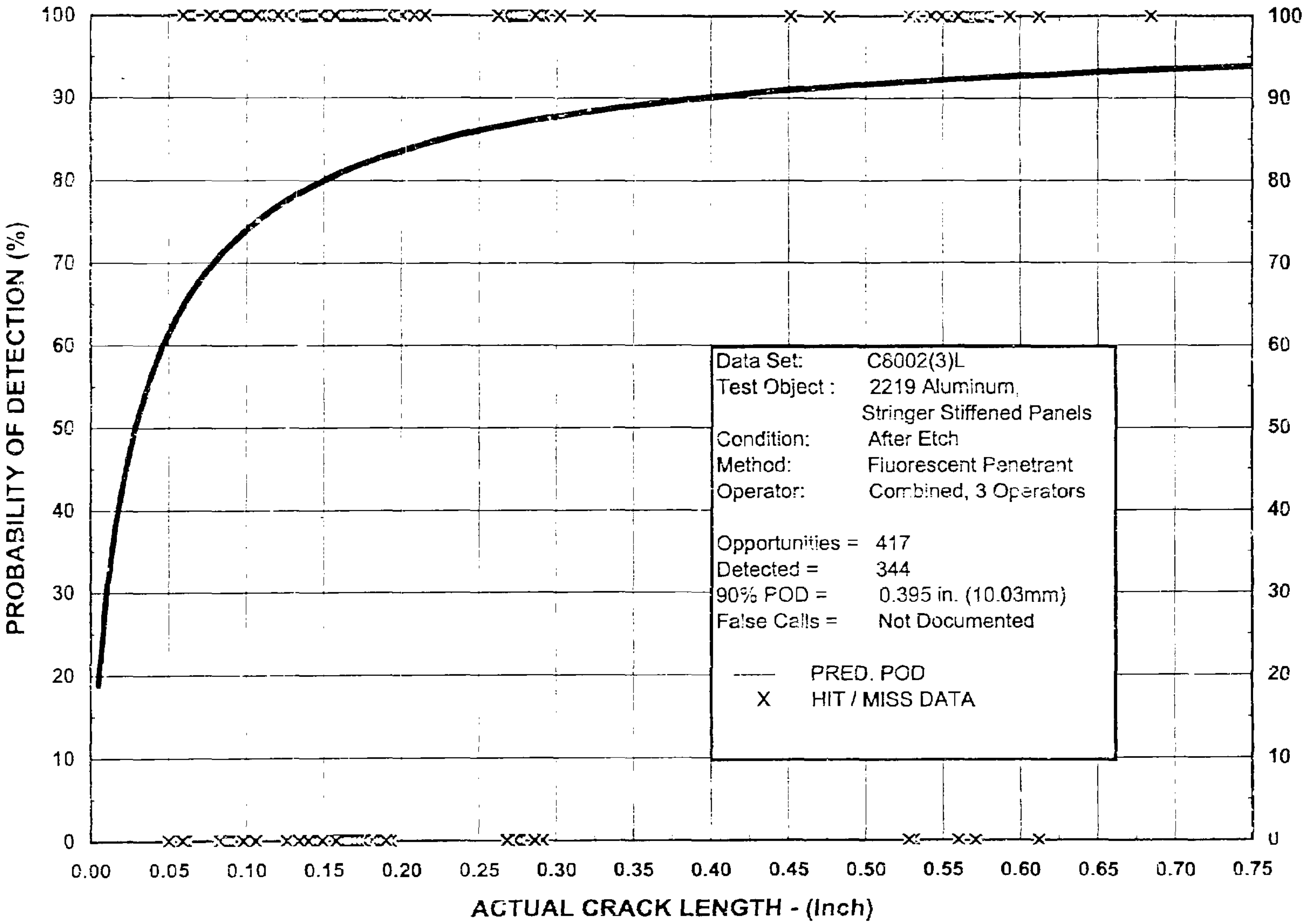
STRINGER STIFFENED PANELS AND RIVETED STIFFENERS ON A FLAT PANEL SUBSTRATE

FLUORESCENT PENETRANT INSPECTION OF AIRCRAFT STRINGER SHAPES



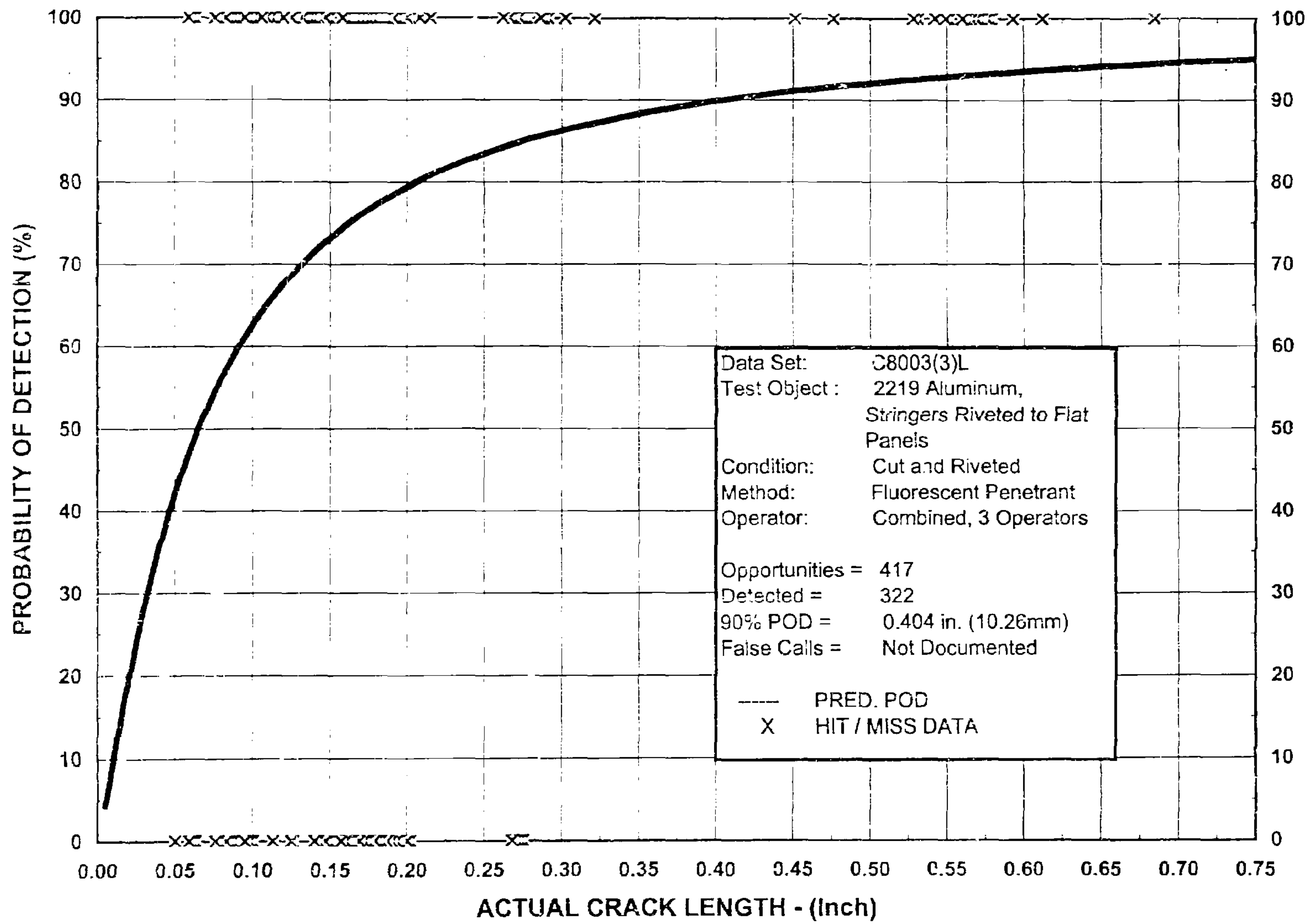
C8001(3)L
6/97 -C8001(3)L

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



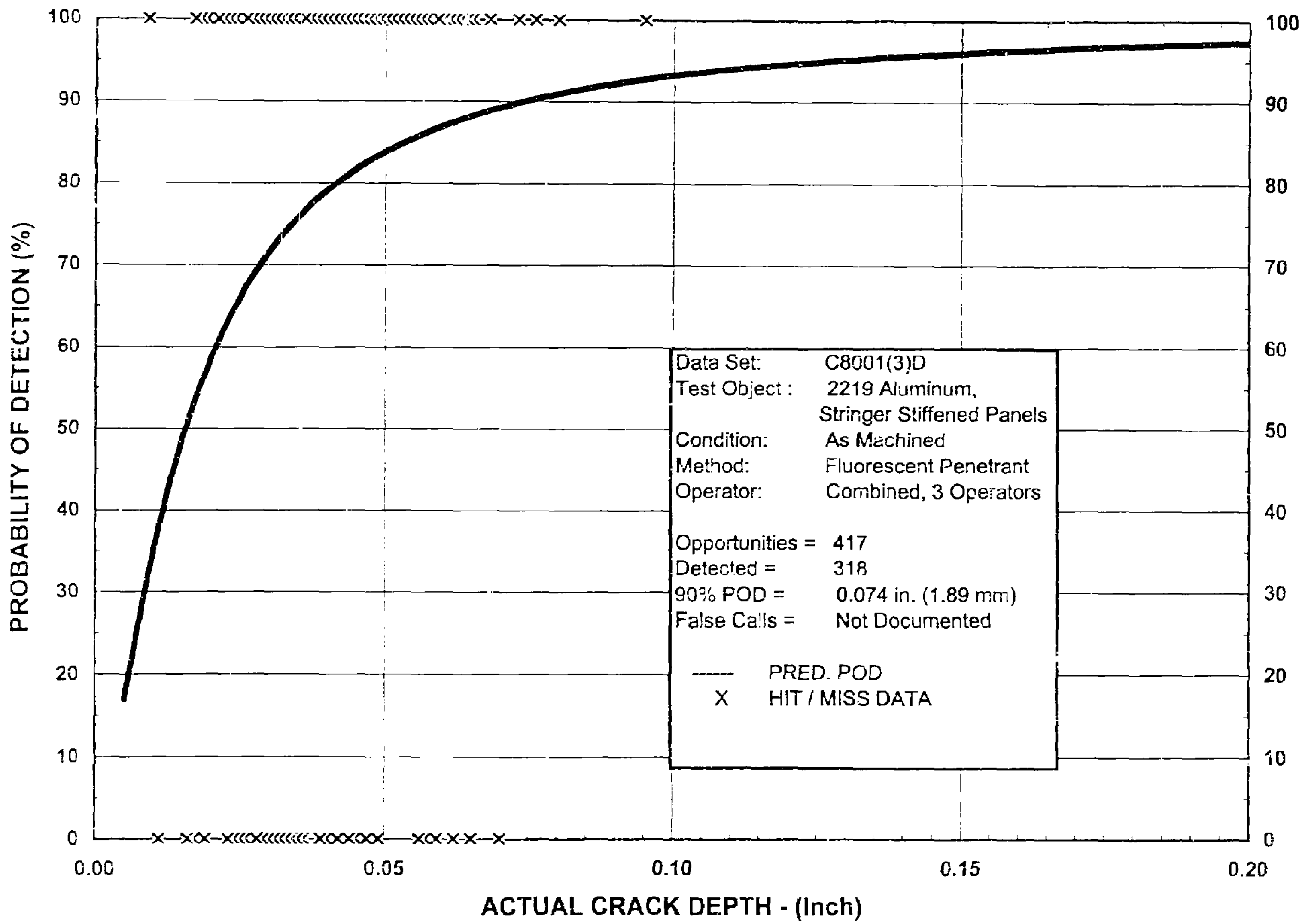
C8002(3)L
6/97 -C8002(3)L

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch



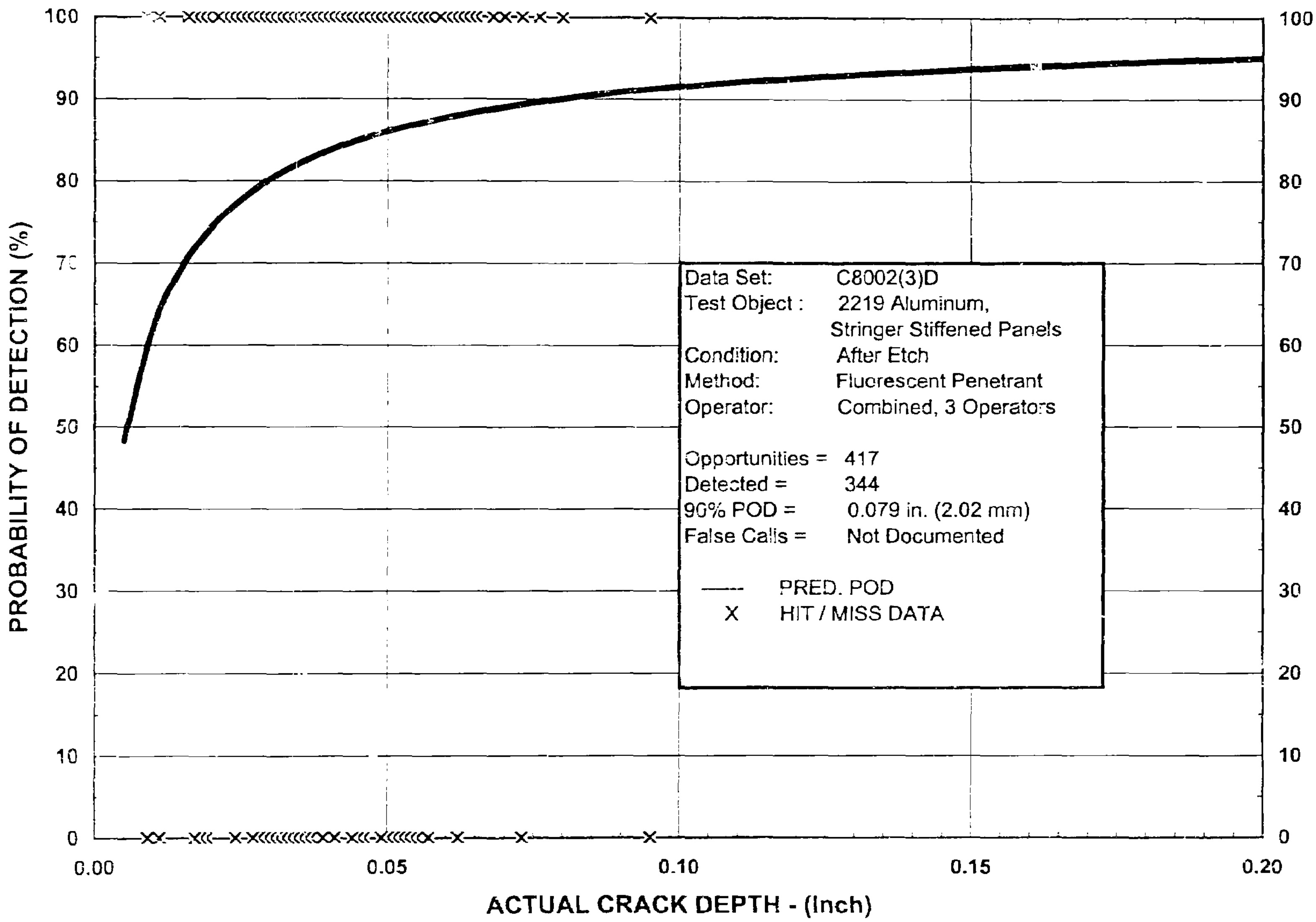
C8003(3)L
6/97 -C8003(3)L

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringers, Riveted to Flat Panels



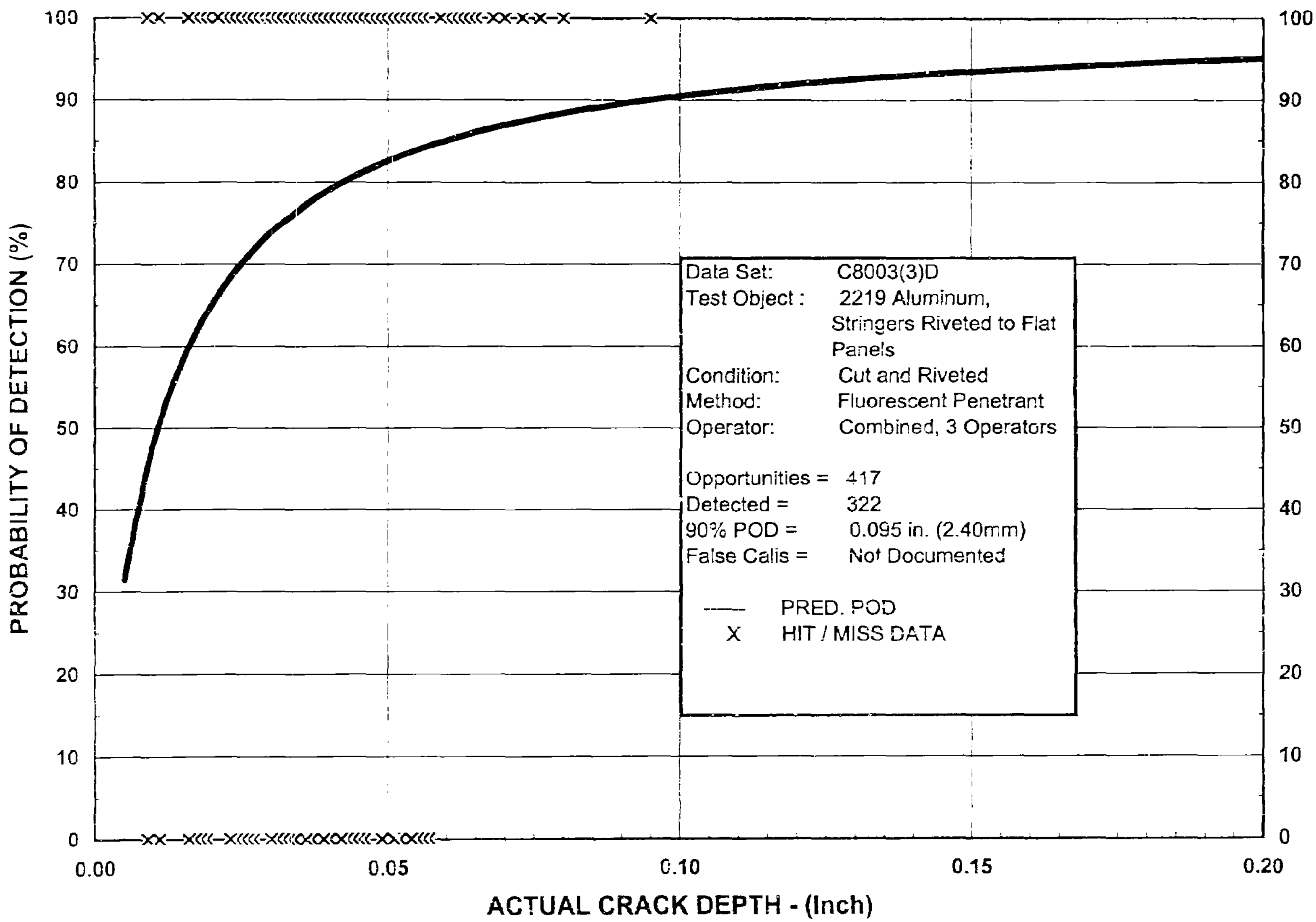
C8001(3)D
6/97 -D8001(3)D

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



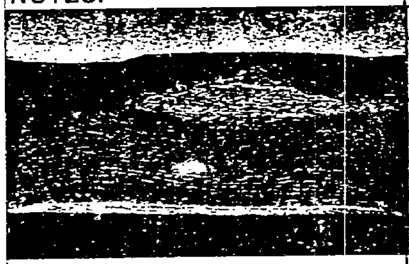
C8002(3)D
6/97 -C8002(3)D

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch

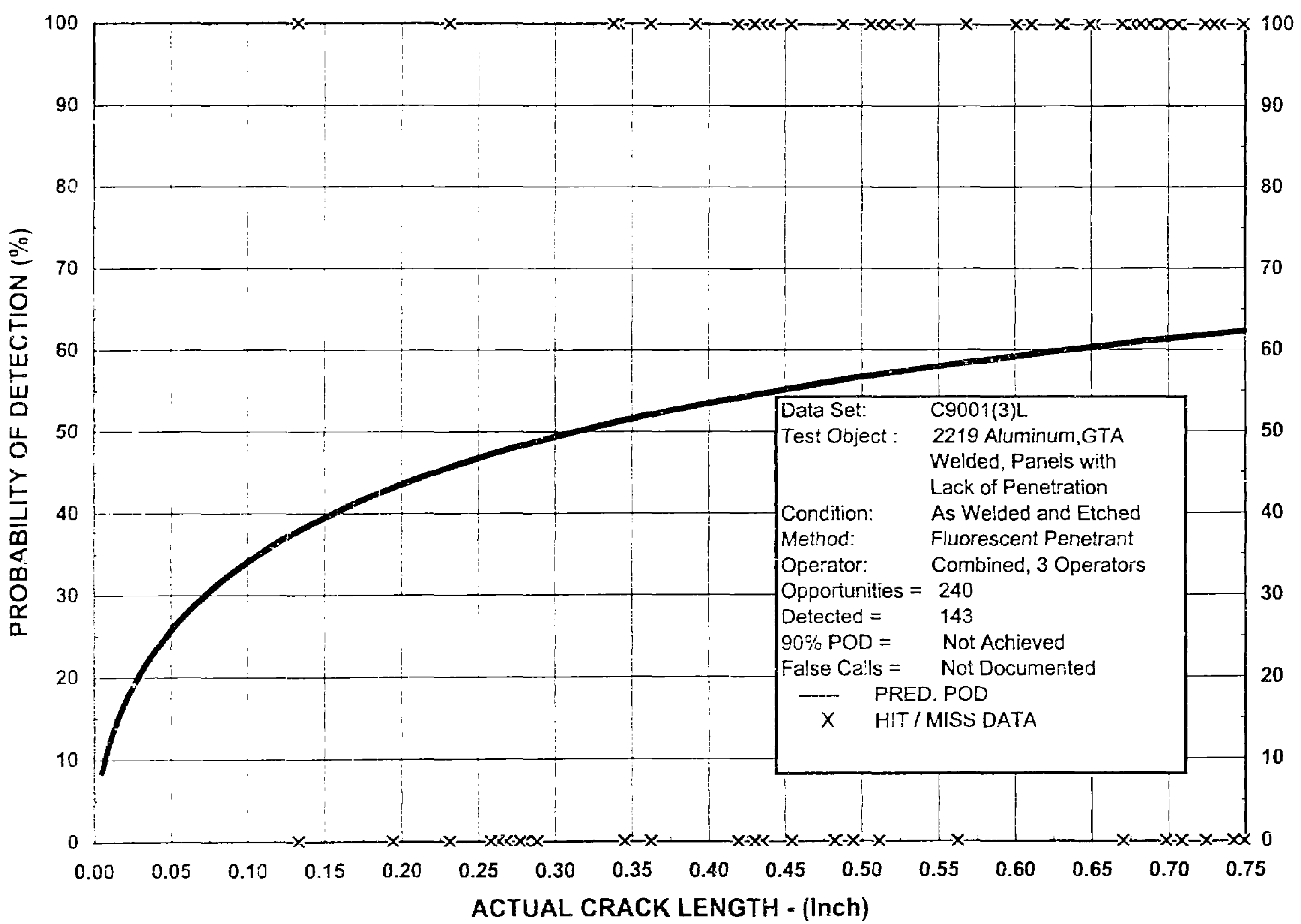


C8003(3)D
6/97 -C8003(3)D

Fluorescent Penetrant - 3 Operators
2219 Aluminum, Stringers, Riveted to Flat Panels

C9000(3)L	DATA SET DESCRIPTION
METHOD:	Fluorescent Penetrant - Solvent Removable
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. One pass from each panel surface.
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE:	Lack of Penetration (LOP) defects / cracks, produced by the two pass weld process
ARTIFACT SHAPE:	Lune shapes with target lengths of 0.250, .500 and 1.00 inch and apex depths of 0.030 to 0.100 inch
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded"; -02."After Scarfing; -03, "After Etch"; and -04, "After Proof Loading".
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	C9001(3)L; C9002(3)L; C9003(3)L; and C9004(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	80 Cracks / 240 opportunities. (Some defects / crack were lost during proof loading)
DETECTED:	-01(3)L = 143; -02(3)L =35 ; -03(3)L = 53; - 04(3)L = 199 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	80 surface open flaws were induced in 43 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length -01 "AS PRODUCED"; -02 "AFTER SCARF"; -03, "AFTER ETCH"; -04"AFTER PROOF"
	A= Not Achieved A= Not Achieved A= Not Achieved A= Not Achieved
	Authors Note: The PENETRANT method is not reliable for this type of defect due to the variable nature of the defect location. Note: Only panels with a surface opening were selected for this assessment.
Test Specimen Descriptions	
in AA000(3)L, Page 2	

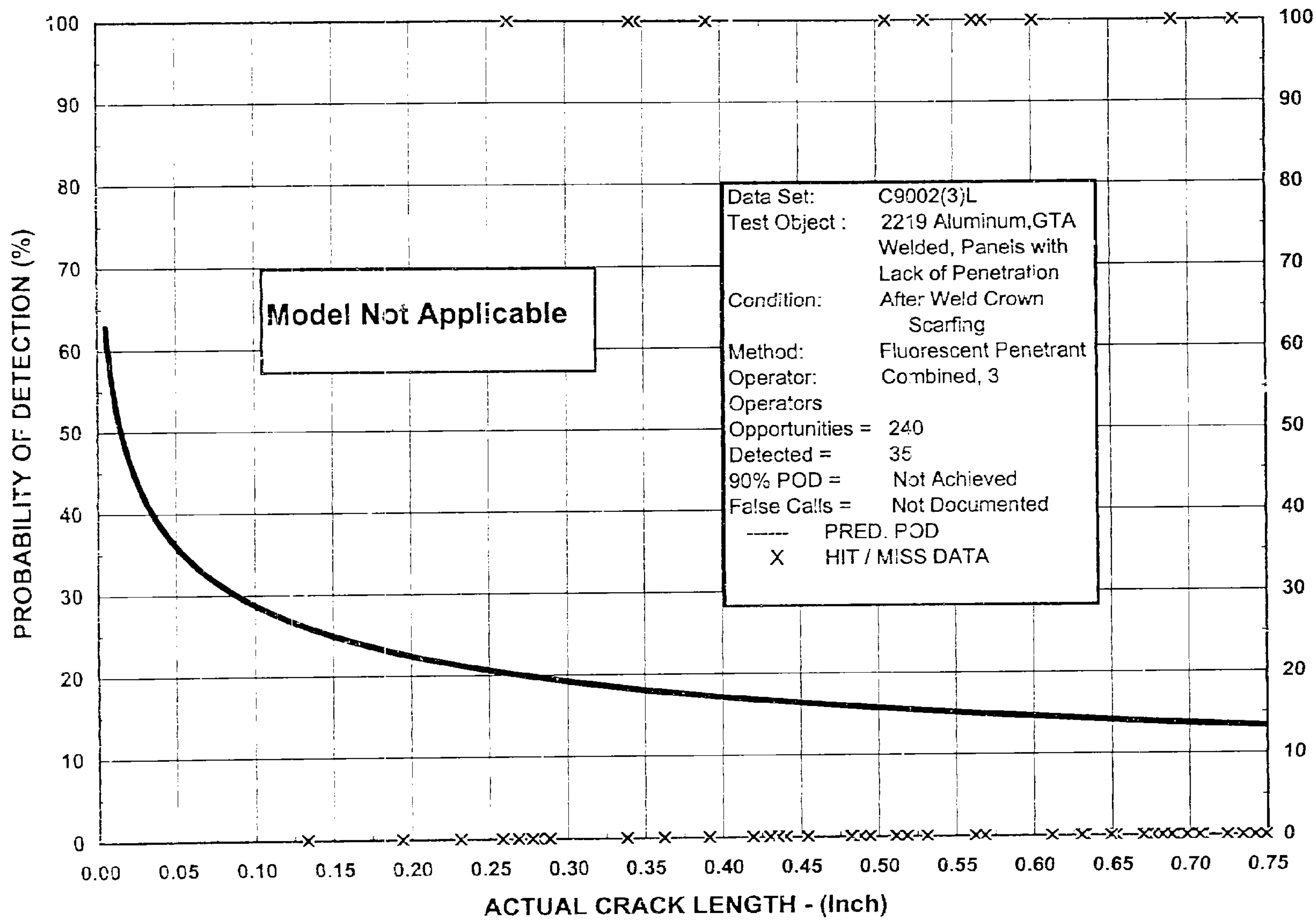
FLUORESCENT PENETRANT INSPECTION
WELD LACK OF PENETRATION (LOP) TEST SPECIMENS



C9001(3)L

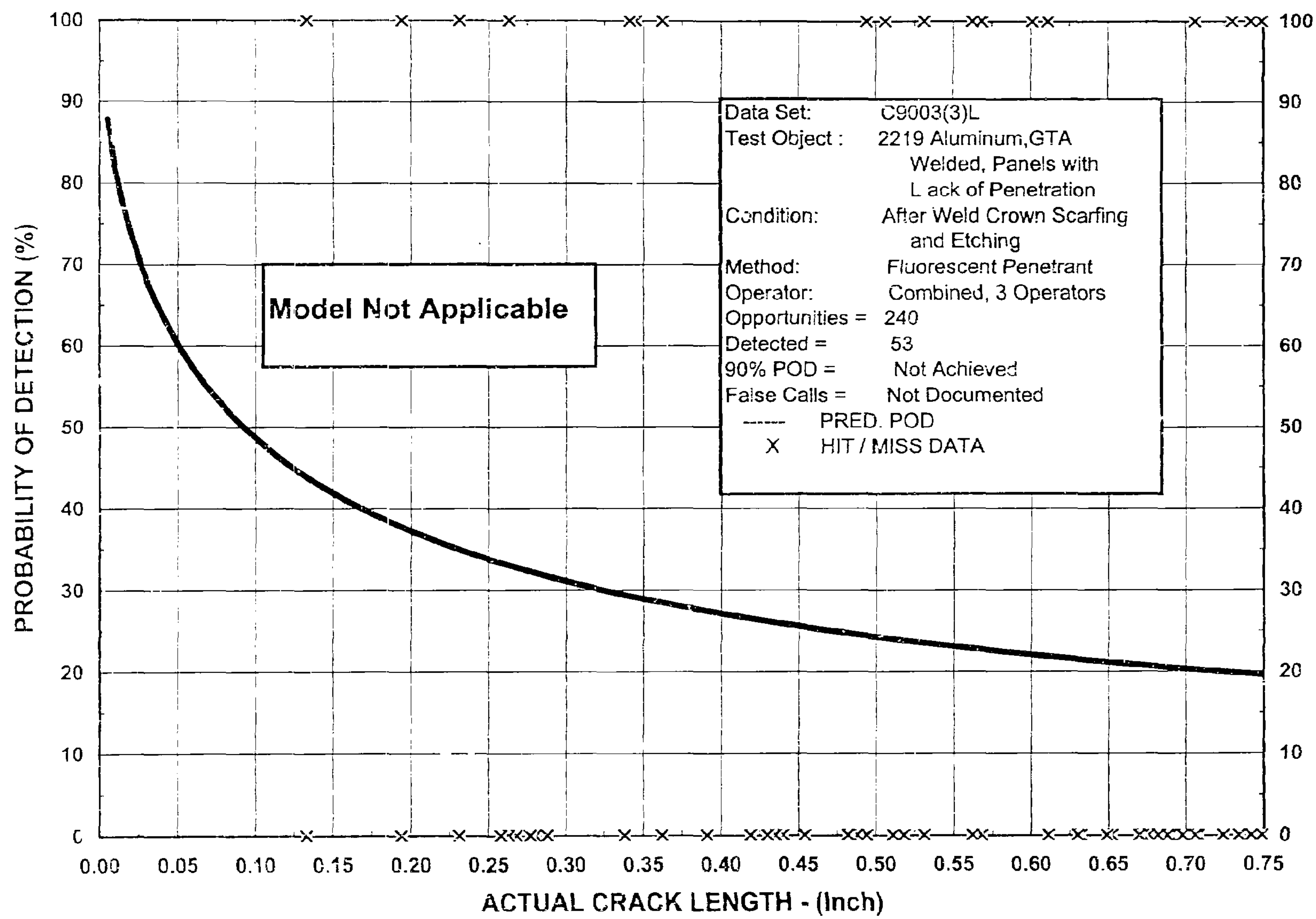
6/97 -C9001(3)L

Fluorescent Penetrant - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration



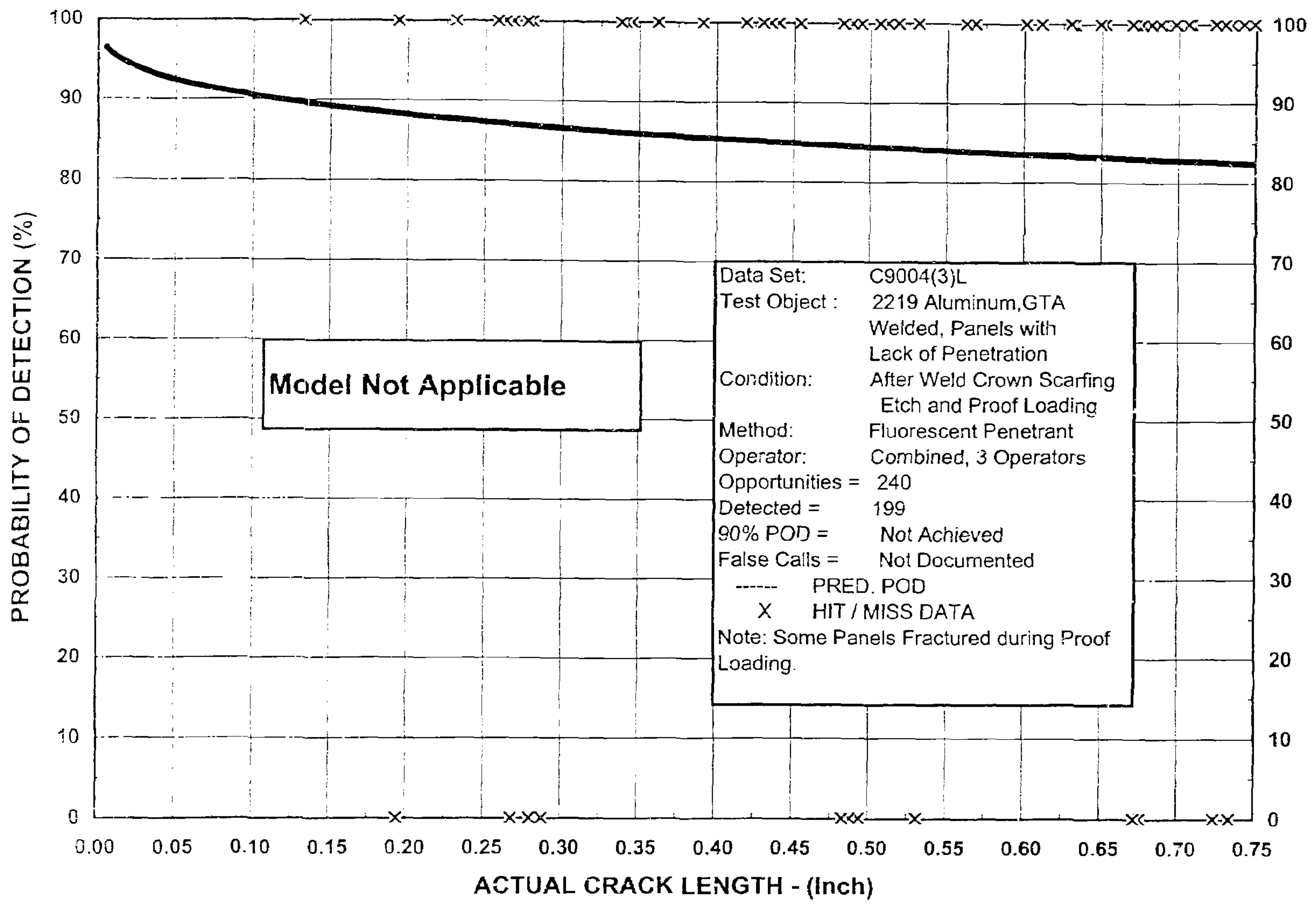
C9002(3)L
6/97 -C9002(3)L

Fluorescent Penetrant - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing



C9003(3)L
6/97 -C9003(3)L

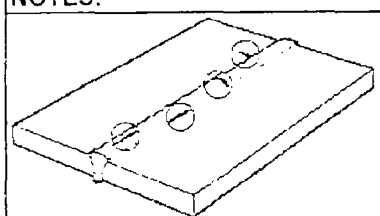
Fluorescent Penetrant - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etching

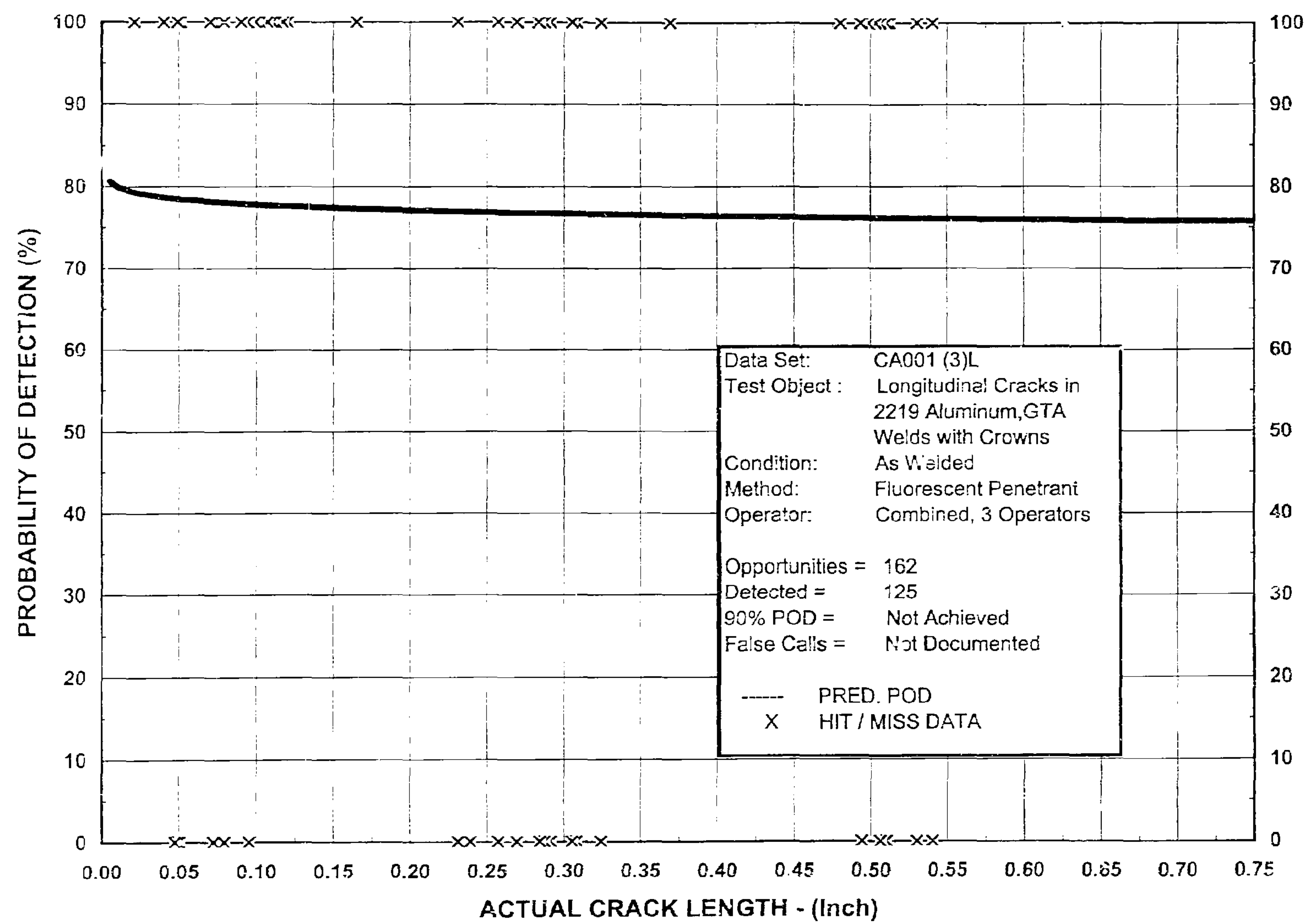


Fluorescent Penetrant - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing, Etching and Proof Loading

C9004(3)L
6/97 -C9004(3)L

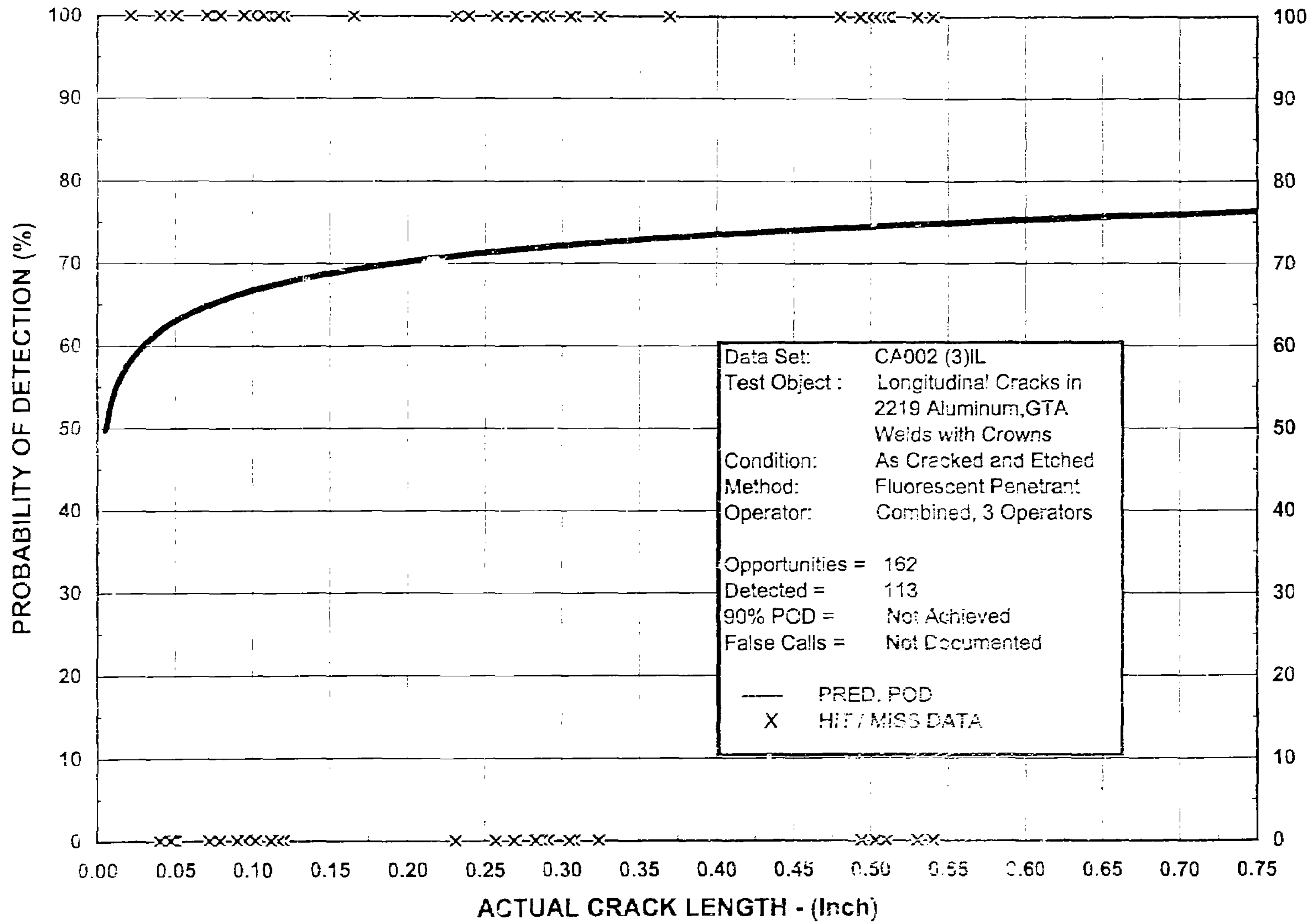
CA000(3)L	**DATA SET DESCRIPTION - LONGITUDINAL WELDS WITH CROWNS**
METHOD:	Fluorescent Penetrant - Solvent Removable
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	CA001(3)L; CA002(3)L; CA003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	162 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 125; -02(3)L = 113 ; -03(3)L = 135 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= Not Achieved A= Not Achieved A= 0.260 in. (6.60 mm
	Authors Note: Poor penetrant performance is attributed to the heavy smeared surface layer resulting from the removal of the starter EDM notch.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	





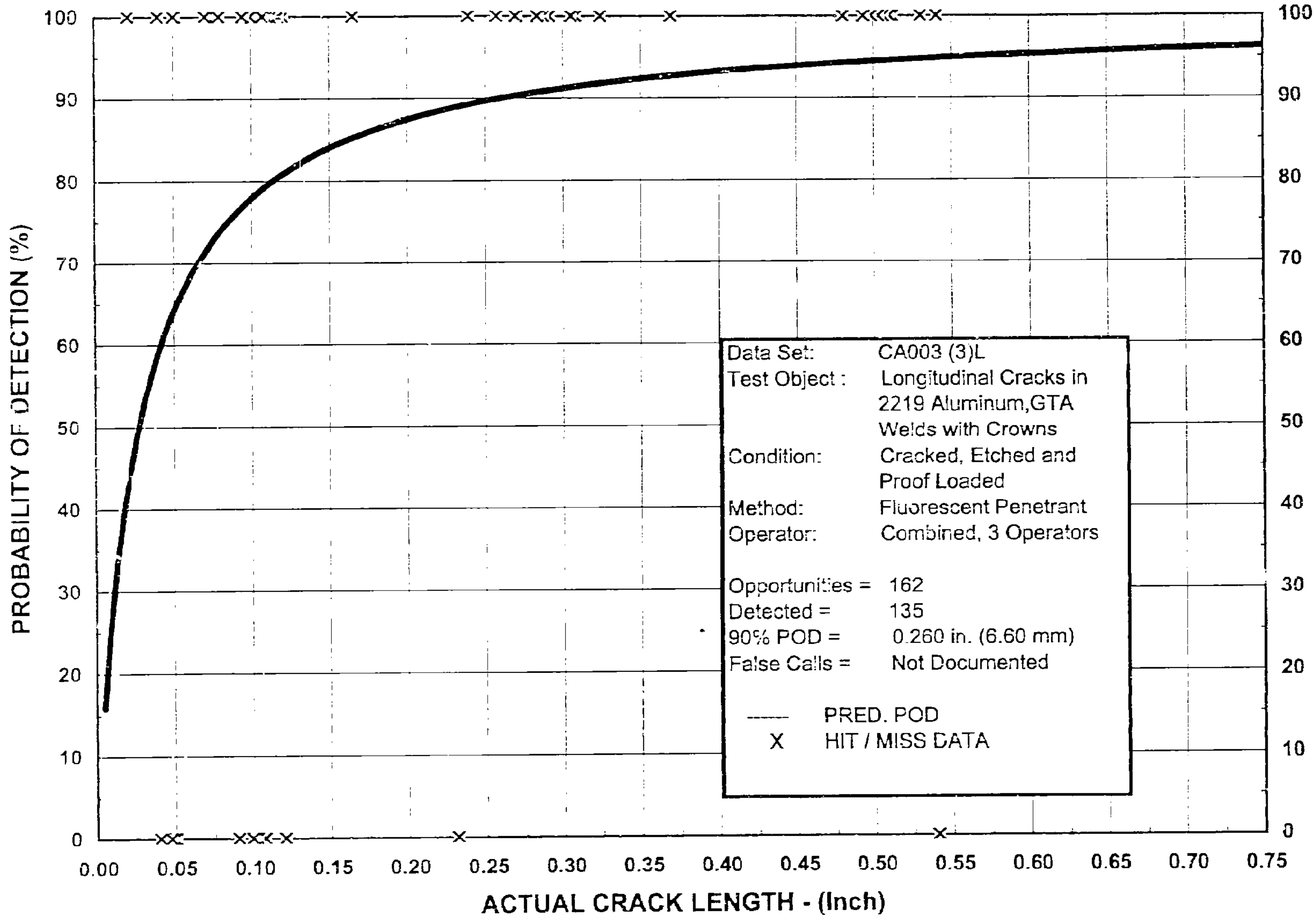
CA001(3)L
6/97 -CA001(3)L

Fluorescent Penetrant - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTAWelds As Cracked and Scarfed



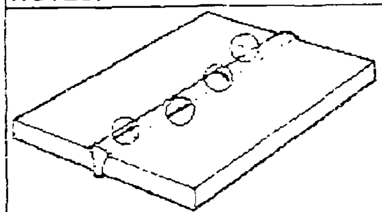
CA002(3)L
6/97 -CA002(3)L

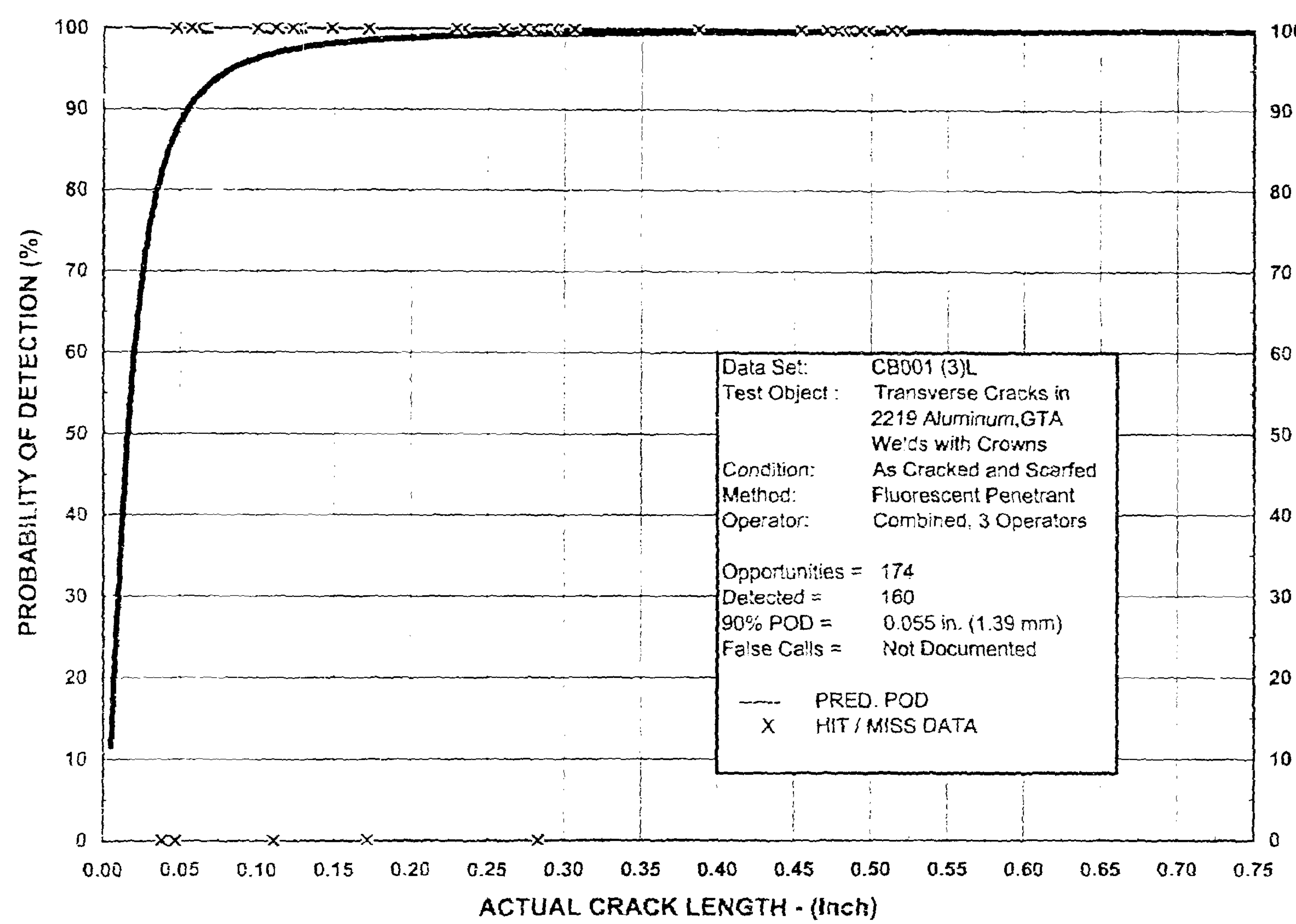
Fluorescent Penetrant - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTAWelds After Etch



CA003(3)L
6/97 -CA003(3)L

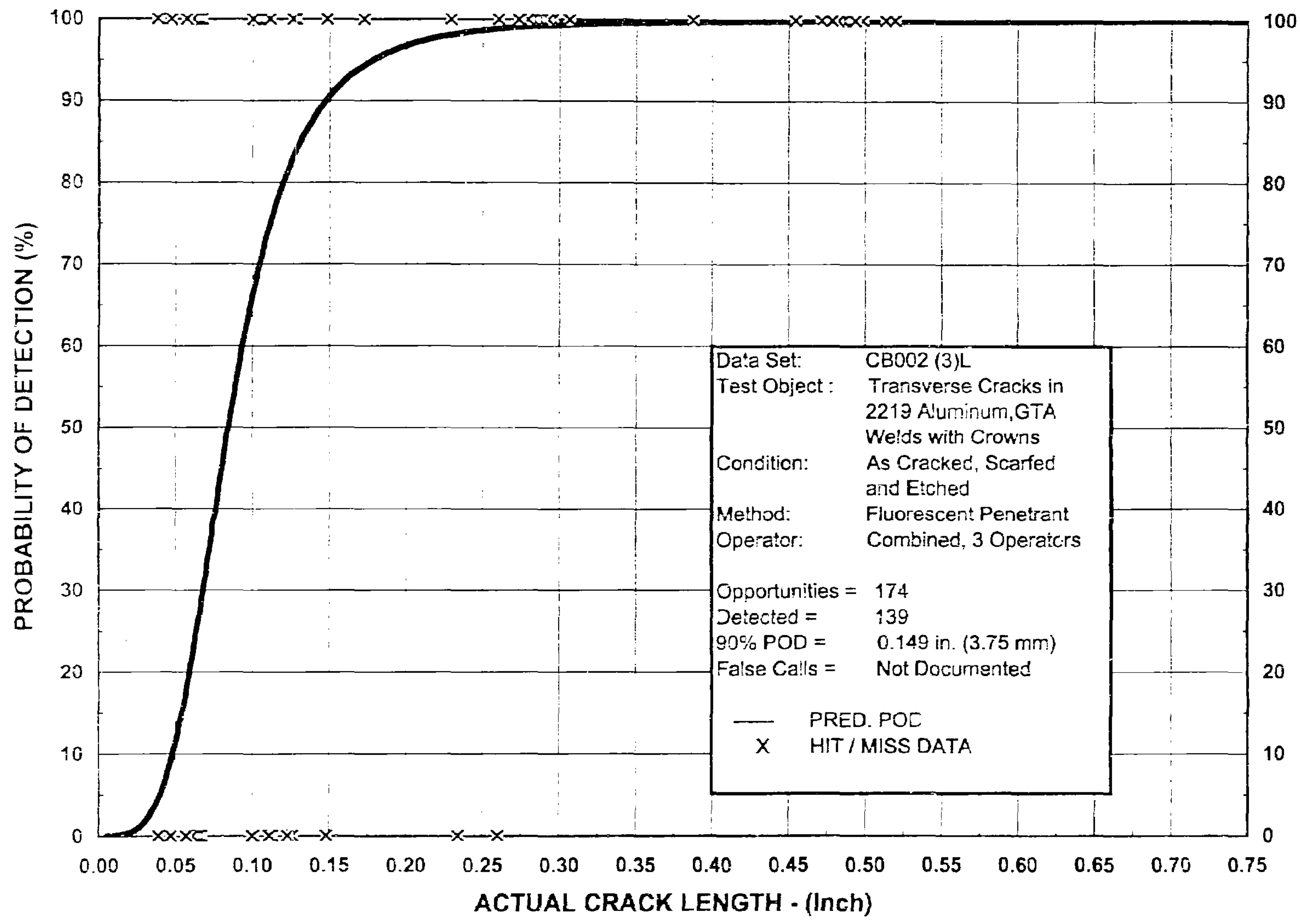
Fluorescent Penetrant - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTAWelds Cracked, Etched and Proof Loaded

CB000(3)L	DATA SET DESCRIPTION - TRANSVERSE CRACKS IN WELDS WITH CROWNS
METHOD:	Fluorescent Penetrant - Solvent Removable
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	CB001(3)L; CB002(3)L; CB003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	174 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 160; -02(3)L = 139 ; -03(3)L = 148 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= 0.055 in. (1.39 mm) A= 0.149 in. (3.75 mm) A= 0.206 in. (5.23 mm)
	Authors Note: Benefits of etching and proof loading are not reflected in this data set.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	



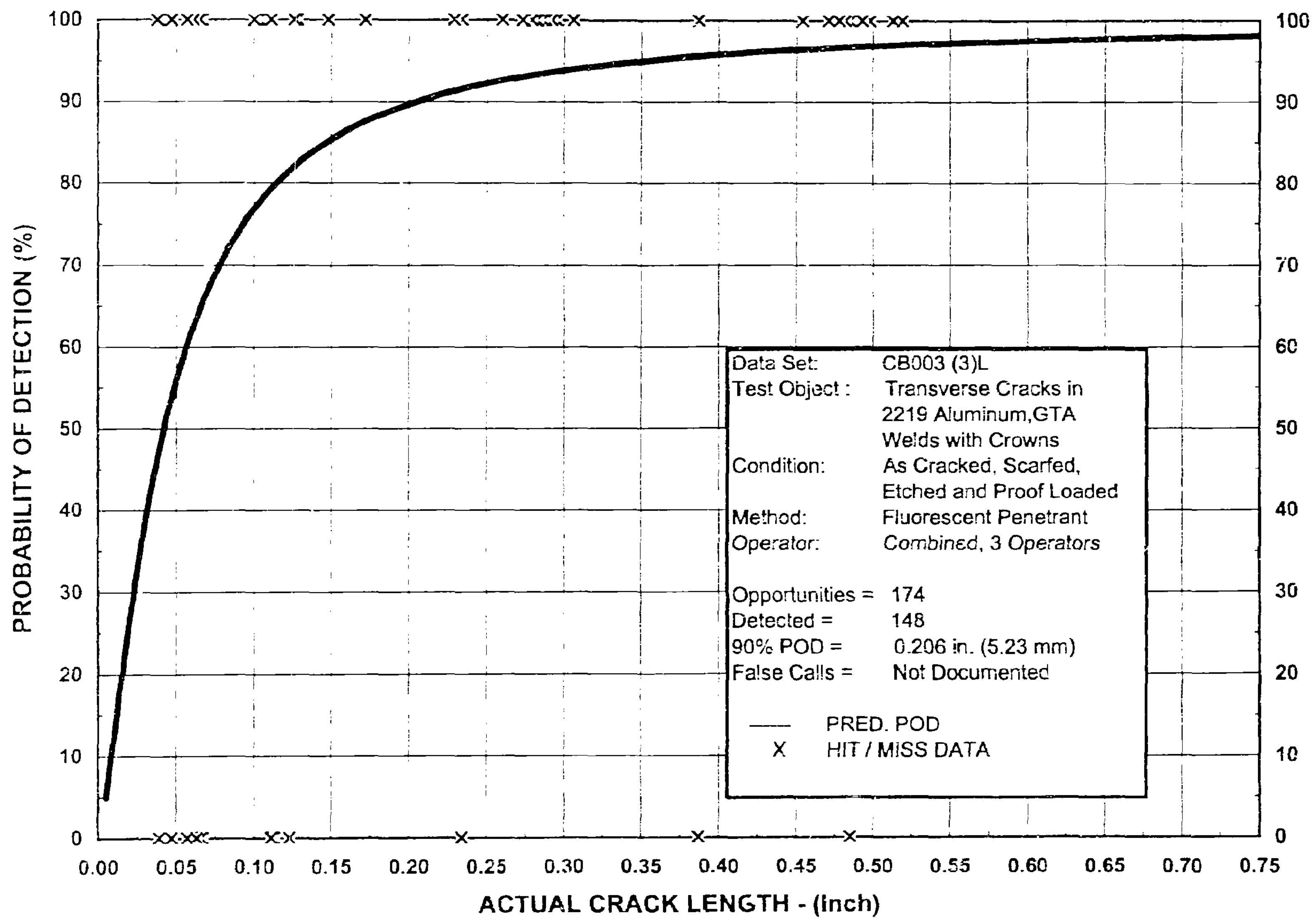
CB001(3)L
6/97 -CB001(3)L

Fluorescent Penetrant - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds After Scarfing



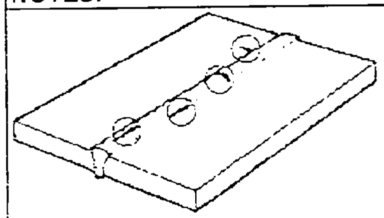
CB002(3)L
6/97 -CB002(3)L

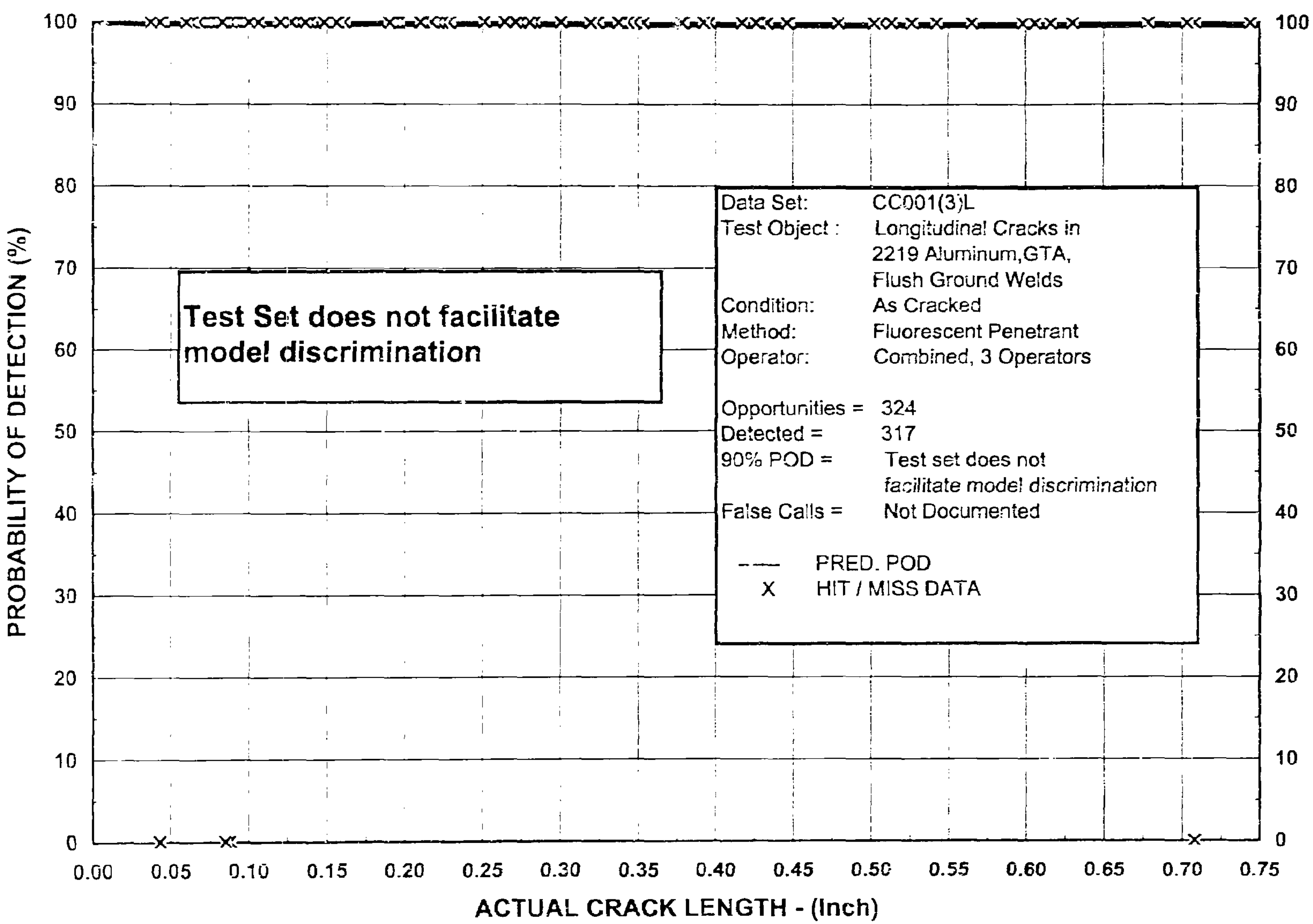
Fluorescent Penetrant - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds After Scarfing and Etching



CB003(3)L
6/97 -CB003(3)L

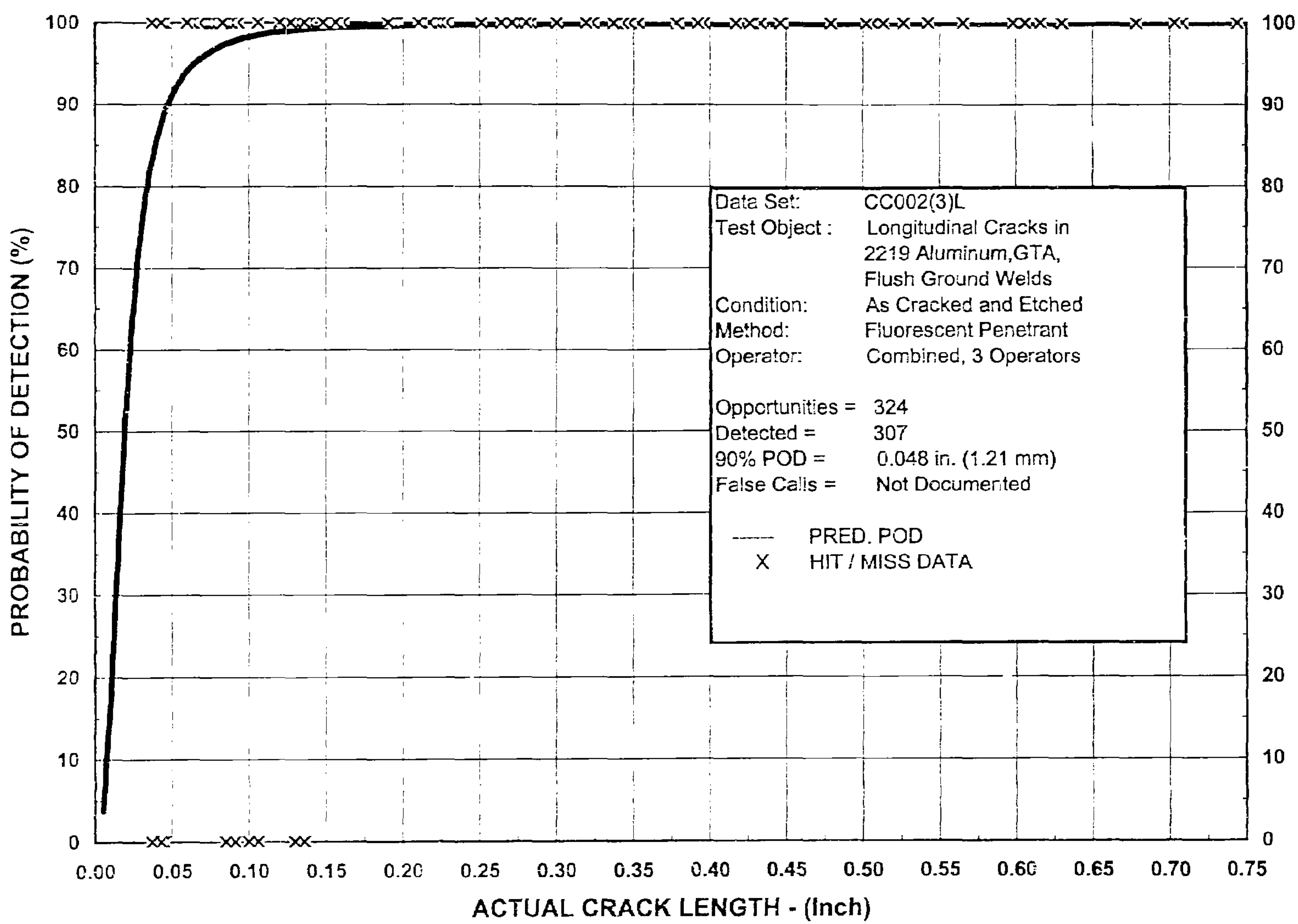
Fluorescent Penetrant - 3 Operators Transverse Fatigue Cracks in 2219 Aluminum GTA Welds Scarfed, Etched and Proof Loaded

CC000(3)L	**DATA SET DESCRIPTION - LONGITUDINAL CRACKS IN FLUSH WELDS**
METHOD:	Fluorescent Penetrant - Solvent Removable
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE.	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch": -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	CC001(3)L; CC002(3)L; CC003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	324 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 317; -02(3)L = 307 ; -03(3)L = 311 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= No Test A= 0.048 in. (1.21 mm) A= 0.039 in. (0.990 mm)
	Authors Note: The crack size distribution provided a high level of detection and therefore does not facilitate good discrimination by the POD model.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	



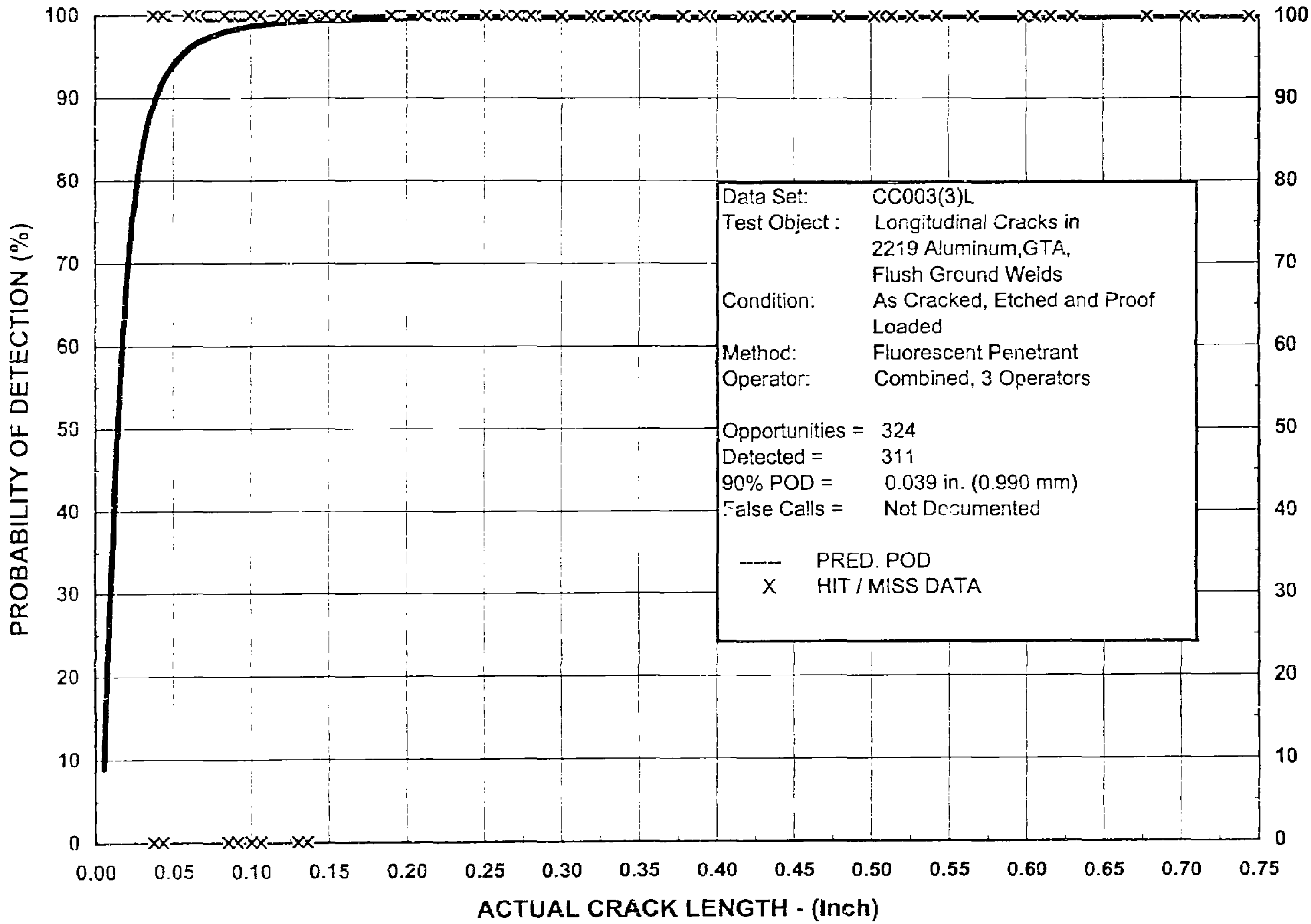
CC001(3)L
6/97 -CC001(3)L

Fluorescent Penetrant - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



CC002(3)L
6/97 -CC002(3)L

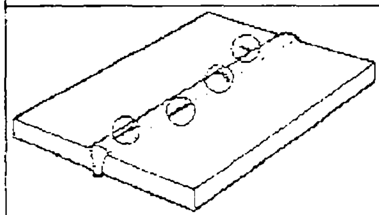
Fluorescent Penetrant - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching

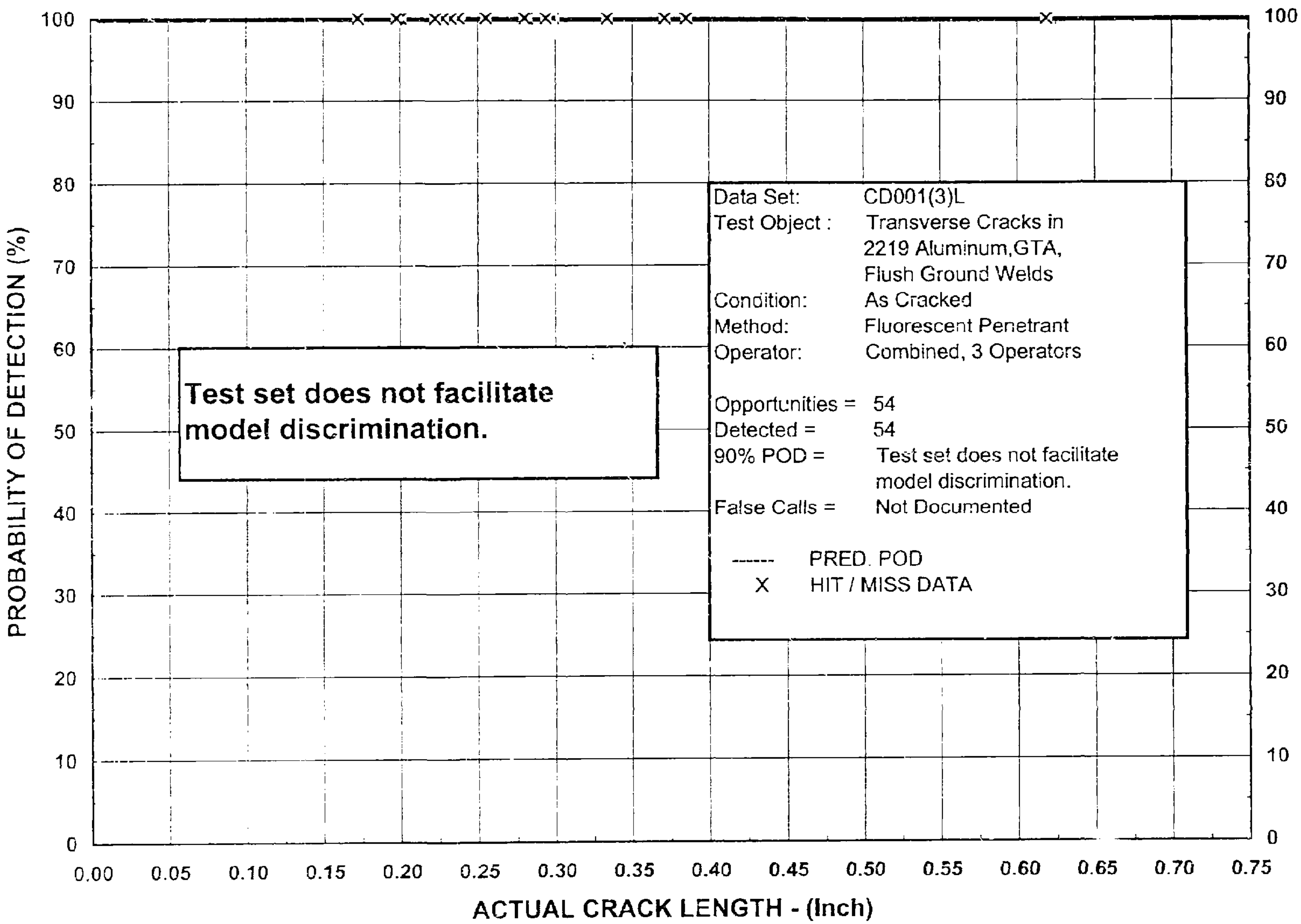


CC003(3)L

6/97 -CC003(3)L

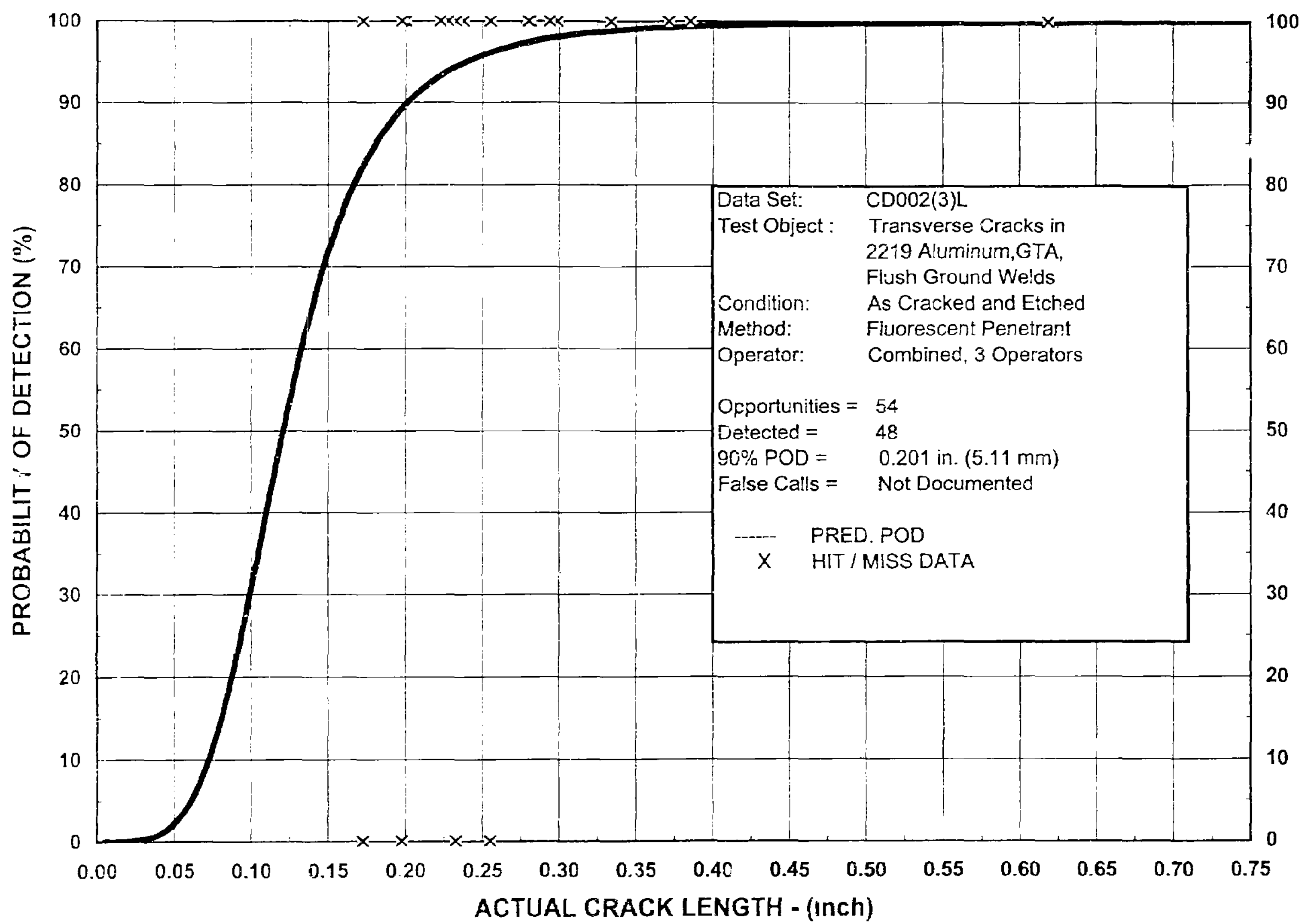
Fluorescent Penetrant - 3 Operators Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading

CD000(3)L	**DATA SET DESCRIPTION - TRANSVERSE CRACKS IN FLUSH WELDS**
METHOD:	Fluorescent Penetrant - Solvent Removable
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Fluorescent Penetrant Inspection; URESCO P-149, Solvent Removable(K-410); D499C Developer
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Hand Application
DATA SET IDENTIFIER:	CD001(3)L; CD002(3)L; CD003(3)L
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	54 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L = 54; -02(3)L = 48 ; -03(3)L = 44 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. *Mullen* **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the *maximum likelihood / log logistic method.*
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	A= No Test A= 0.201 in. (5.11 mm) A= 0.218 in. (5.28 mm)
	Authors Note: This test set was too small to provide good discrimination by the analysis model.
Test Specimen Descriptions	
in AB000(3)L, Page 2.	



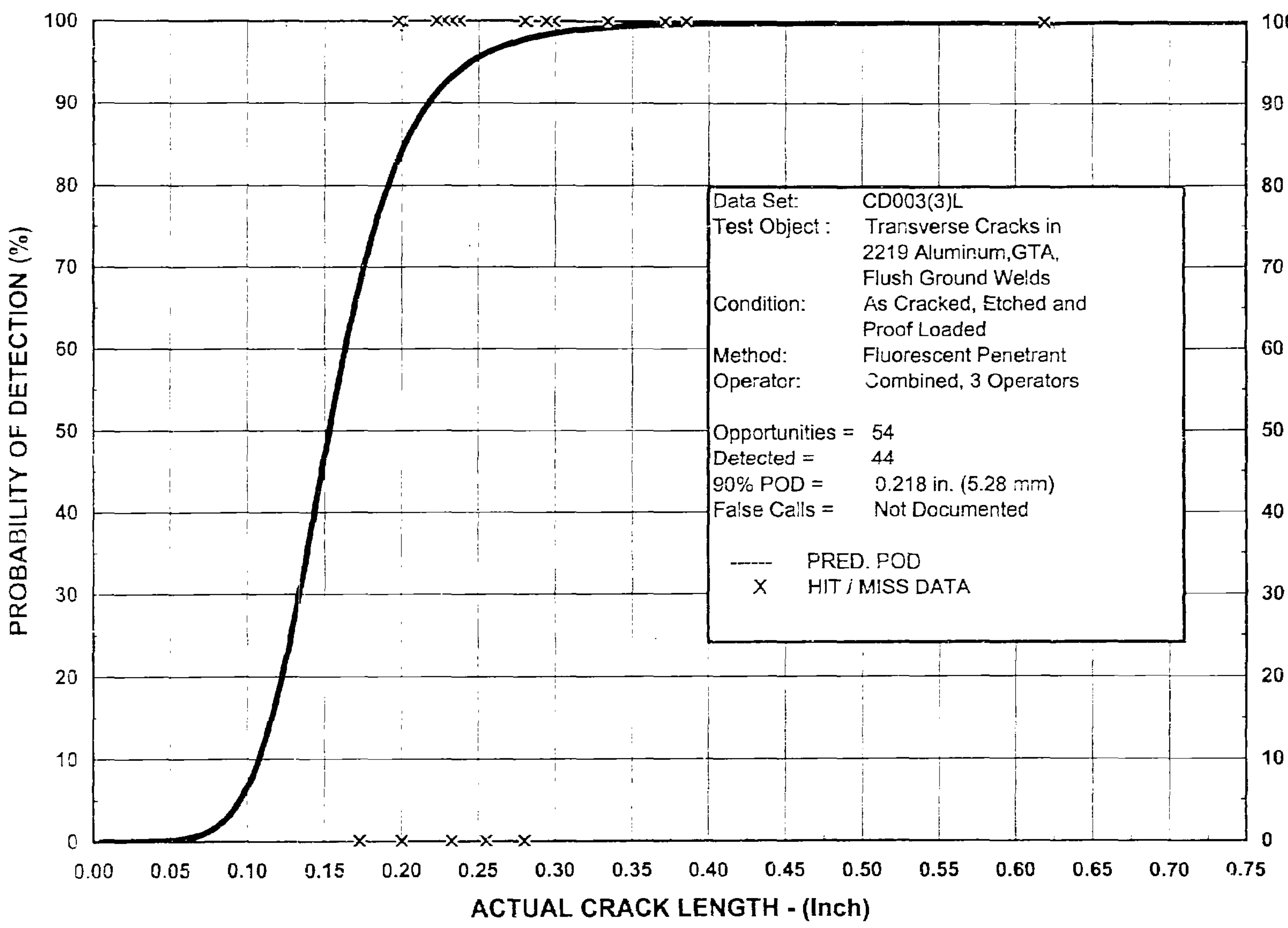
CD001(3)L
8/97 -CD001(3)L

Fluorescent Penetrant - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



CD0_2(3)L
8/97 -CD002(3)L

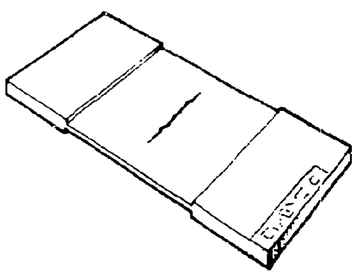
Fluorescent Penetrant - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching



CD003(3)L
8/97 -CD003(3)L

Fluorescent Penetrant - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading

CE000(6)L,D	DATA SET DESCRIPTION FLAT PANEL, HAYNES 188
METHOD:	Water Washable Fluorescent Penetrant
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Fluorescent Penetrant Manual - Sherwin I-319 diluted 50/50 with water; W/WO Sherwin D-100 Aq. Developer
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Surface measurement of crack length; Crack depth predication bases on validated crack growth procedure.
MATERIAL:	Haynes 188 Alloy, annealed condition (AMS 5608A)
TEST OBJECT THICKNESS:	0.190 inch nominal final thickness(From 0.250 inch thick stock)
TEST OBJECT CONDITION:	All inspections performed after machining and etching. Special cleaning procedures between inspections
SURFACE FINISH:	125 RMS or better - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	CE0X1 Inspections with no developer; CE0X2 Inspections with aqueous wet developer
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	284 Cracks of either side of 85 panels; 17 unflawed panels (102 total); 1020 total test opportunities
DETECTED:	See data table
FALSE CALLS:	Included on each POD curve
REFERENCES:	Christner, Brent K. and Ward D. Rummel, <u>NDE Detectability of Fatigue Type Cracks in High Strength Alloys</u>, NASA Contract NAS8-34425, National Aeronautics and Space Administration. Marshall Space Flight Center, July 1983 and
	Christner, Brent K, Donald L. Long and Ward D. Rummel, <u>NDE Detectability of Fatigue Type Cracks in High Strength Alloys - NDI Reliability Assessments</u>. NASA Contract NAS8-35503, NASA, Marshall Space Flight Center, September 1988.
DATE:	August 1983 - September 1988
WORK SPONSOR:	John Knadler, NASA, Marshall Space Flight
PERFORMING ORGANIZATION:	Martin Marietta Astronautics Group, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle production and maintenance.
	Flaws were induced in 85 panels (both sides). Seventeen blank panels were included for a total of 102 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	MATRIX OF TEST RESULTS ON THE FOLLOWING PAGE (SHEET 2)



HAYNES 188 - CASE A FLAW

Development Flaw # GL/1

Flaw Length - 0.255"

Flaw Depth - 0.036"

HAYNES 188 - CASE B FLAW

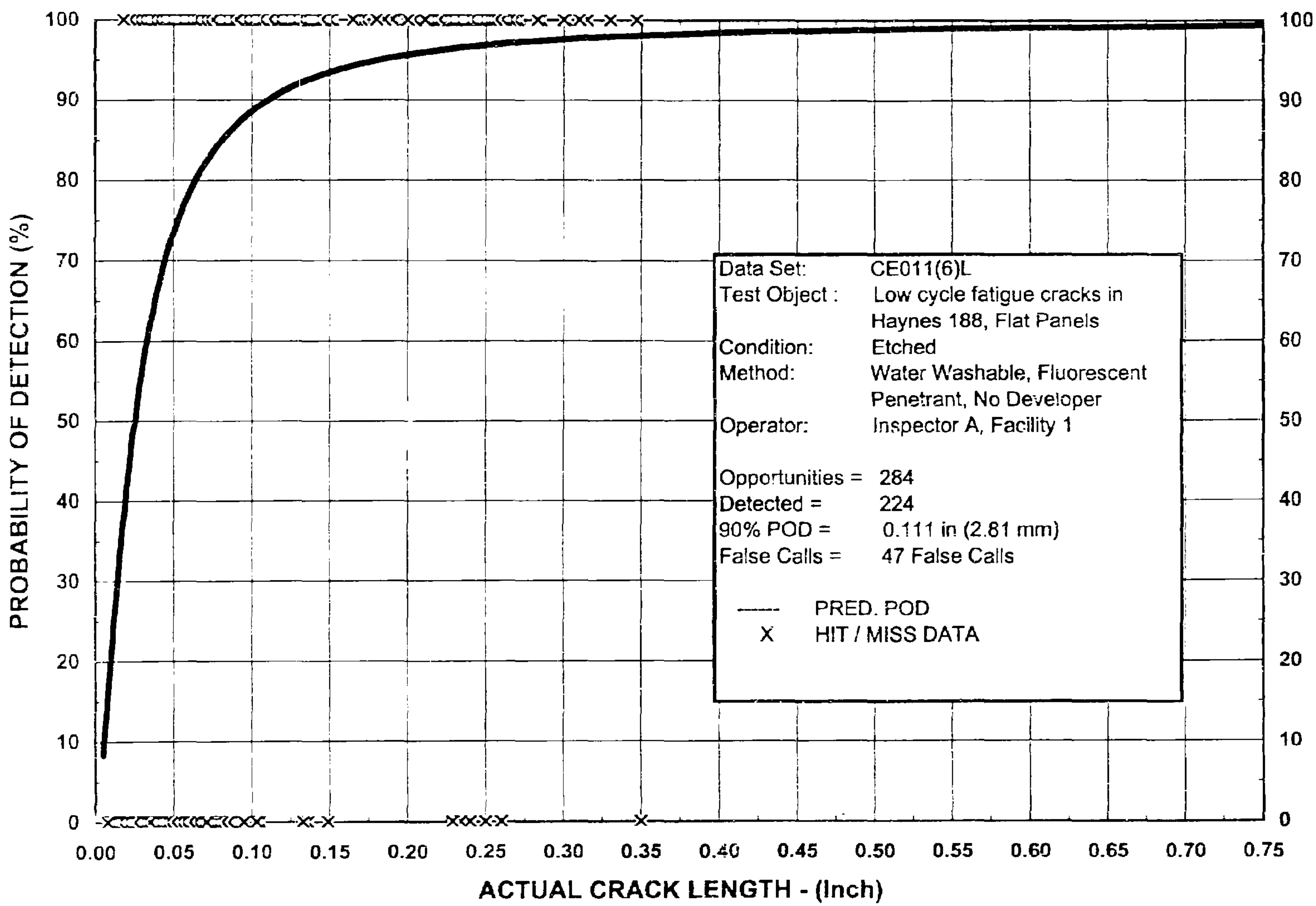
Development Flaw # EC/4

Flaw Length - 0.139"

Flaw Depth - 0.061"

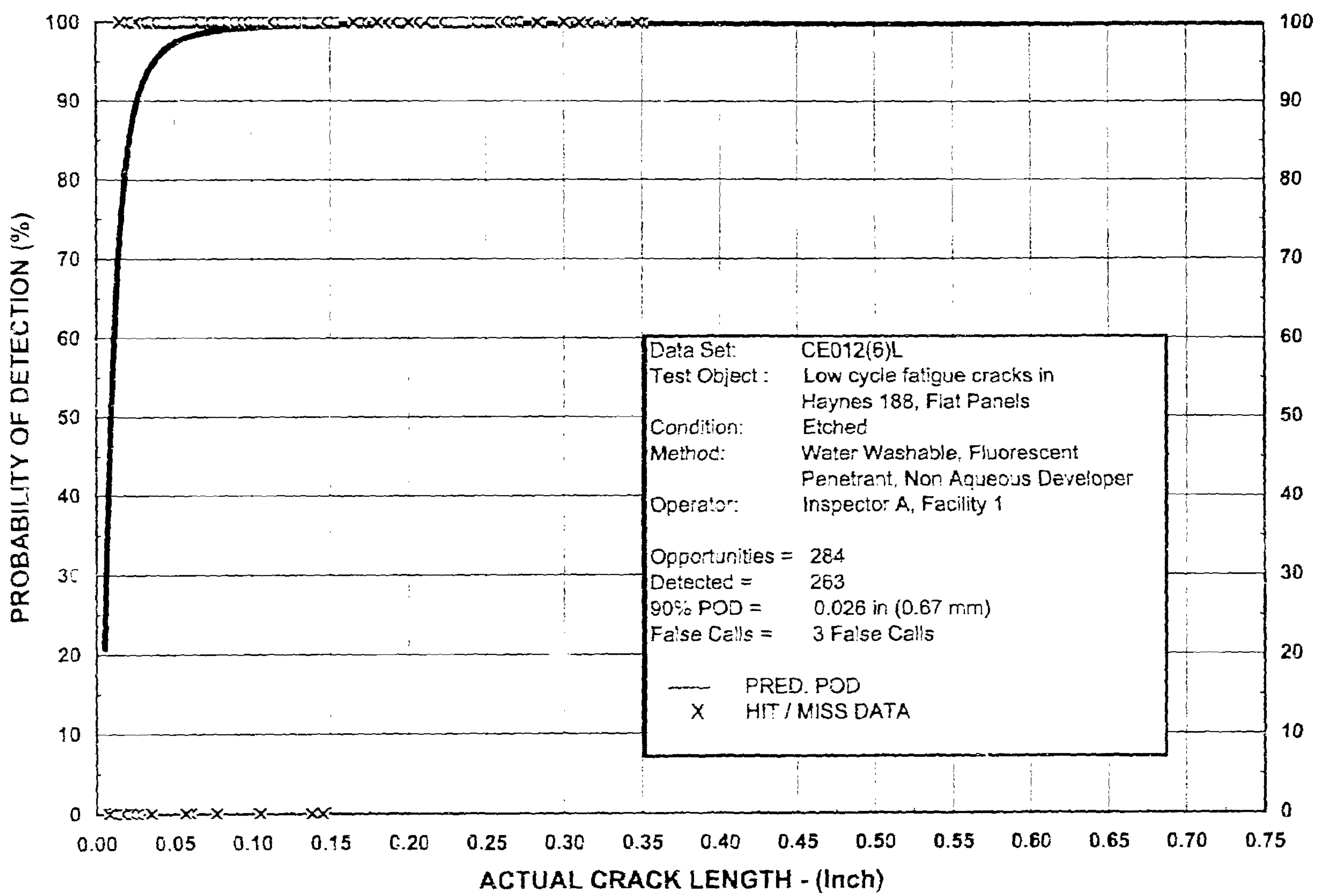
CE000(6)L,D		DATA SET DESCRIPTION FLAT PANEL, HAYNES 188				
METHOD:		Water Washable Fluorescent Penetrant				
	IDENTIFIER	OPP.	DET.	90% POD WITHOUT DEVELOPER	90% POD WITH AQUEOUS WET DEVELOPER	FALSE CALLS
1	CE011(6)L	284	224	0.111 in. (2.81 mm)		47
2	CE011(6)D	284	224	0.027 in. (0.670 mm)		47
3	CE012(6)L	284	263		0.026 in. (0.067 mm)	3
4	CE012(6)D	284	263		Not Achieved	3
5	CE021(6)L	284	86	Not Achieved		70
6	CE021(6)D	284	86	Not Achieved		70
7	CE022(6)L	284	249		0.060 in. (1.52 mm)	5
8	CE022(6)D	284	249		0.012 in. (0.304 mm)	5
9	CE031(6)L	284	93	Not Achieved		47
10	CE031(6)D	284	93	Not Achieved		47
11	CE032(6)L	284	219		0.117 in. (2.97 mm)	16
12	CE032(6)D	284	219		0.024 in. (0.598 mm)	16
13	CE041(6)L	284	57	Not Achieved		23
14	CE041(6)D	284	57	Not Achieved		23
15	CE042(6)L	284	173		0.182 in. (4.61 mm)	49
16	CE042(6)D	284	173		0.035 in. (0.900 mm)	49
17	CE051(6)L	284	198	0.314 in. (7.98 mm)		91
18	CE051(6)D	284	198	0.060 in. (1.54 mm)		91
19	CE052(6)L	284	251		0.065 in. (1.66 mm)	27
20	CE052(6)D	284	251		0.013 in. (0.328 mm)	27
21	CE061(6)L	284	210	0.182 in. (4.61 mm)		20
22	CE061(6)D	284	210	0.036 in. (0.915mm)		20
23	CE062(6)L	284	249		0.069 in. (1.76 mm)	5
24	CE062(6)D	284	249		0.014 in. (0.346 mm)	5
25	CE071(6)L	284	167	0.307 in. (7.80 mm)		33
26	CE071(6)D	284	167	0.067 in. (1.69 mm)		33
27	CE072(6)L	284	242		0.072 in. (1.85 mm)	0
28	CE072(6)D	284	242		0.014 in. (3.62 mm)	0
29	CE081(6)L	284	50	Not Achieved		95

NOTE: The preceding inspections were conducted with a black light illumination level of 1200 microwatts / square centimeter. CE081(6)L was conducted with a black light illumination level of 400 microwatts /square centimeter. The background white light level for all inspections was 5-10 foot candles and thus exceeded the 2 foot candle level that is recommended by industry standards.



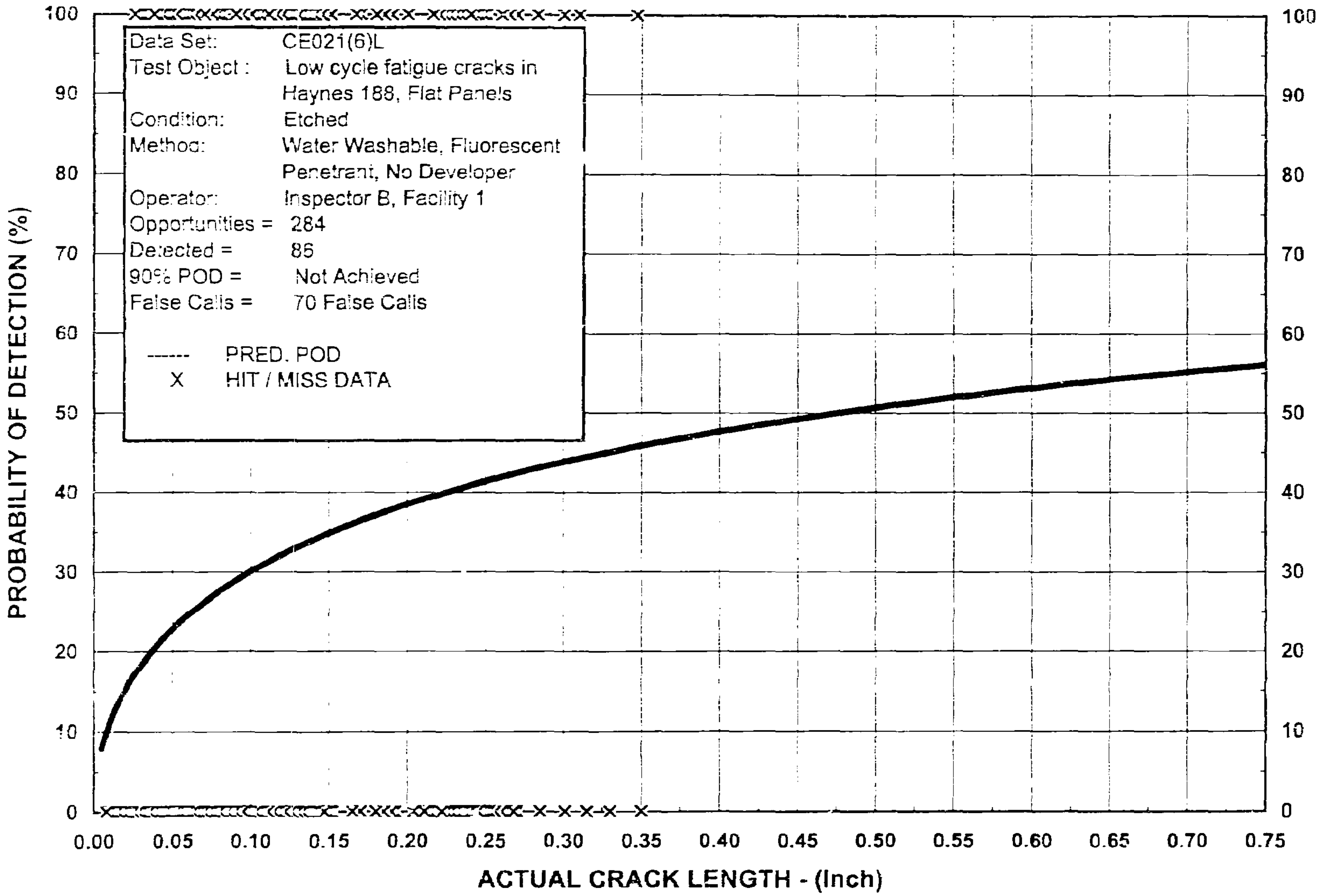
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE011(6)L
11/97 -CE011(6)L



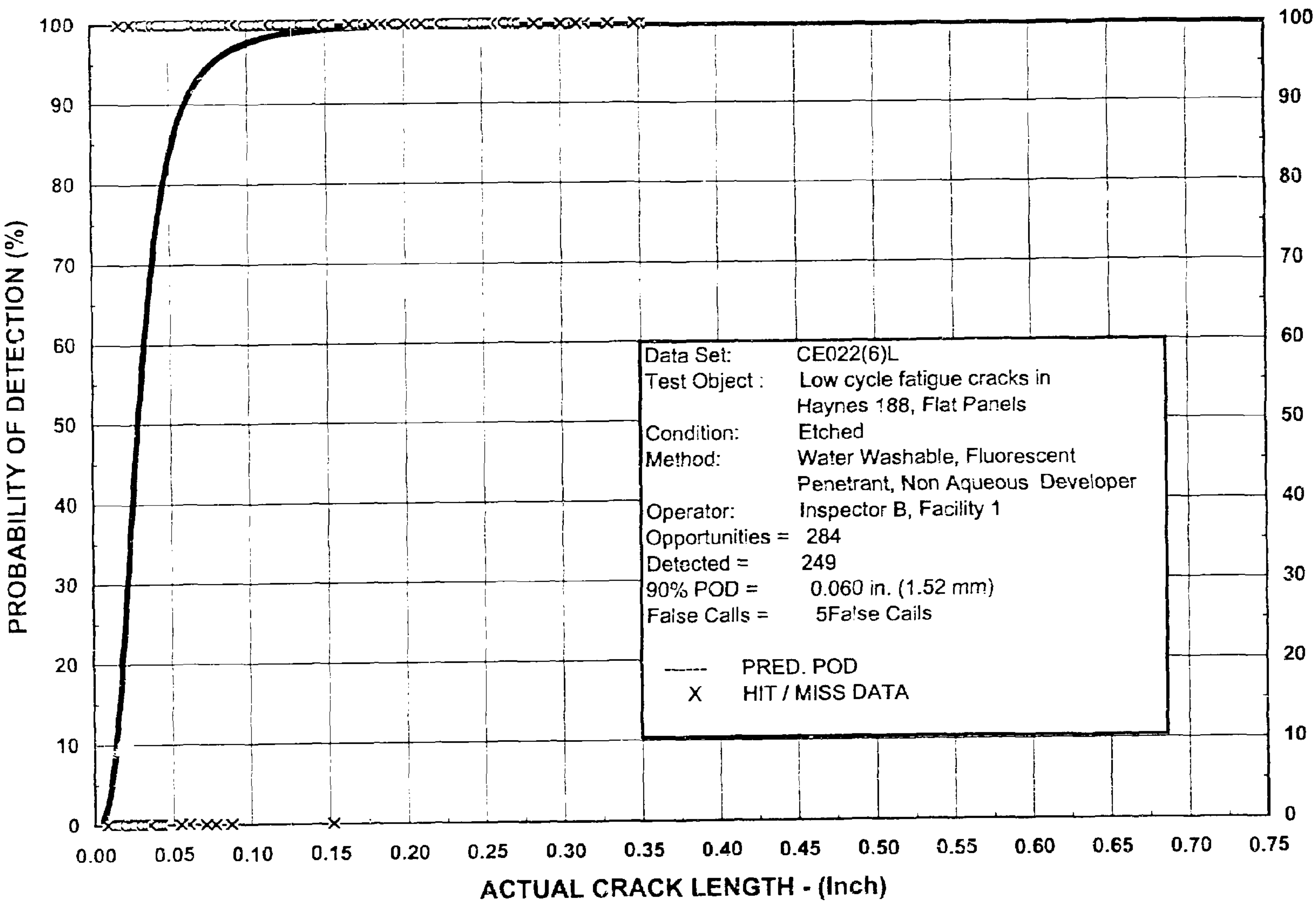
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE012(6)L
11/97 -CE012(6)L



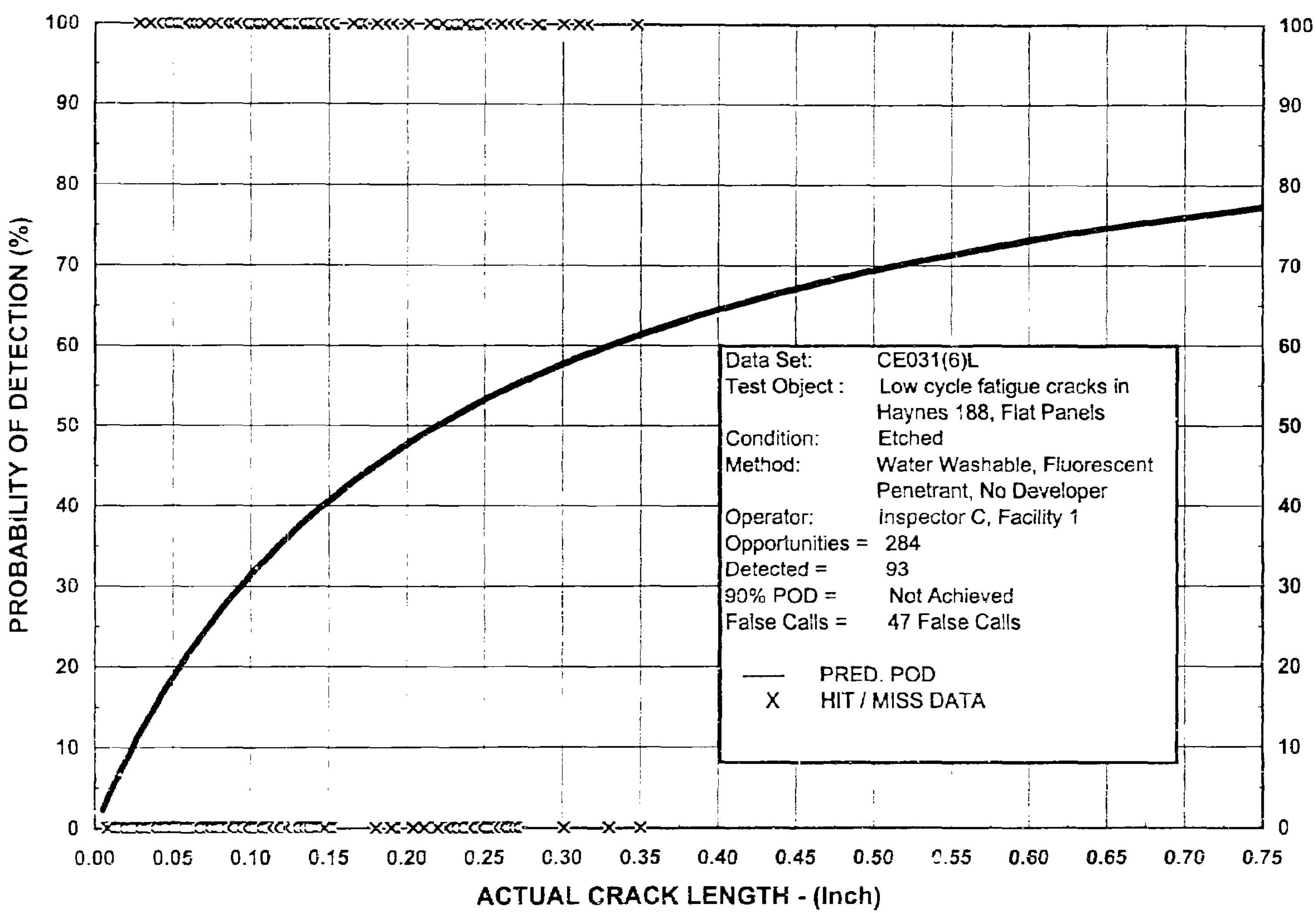
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE021(6)L
11/97 -CE021(6)L



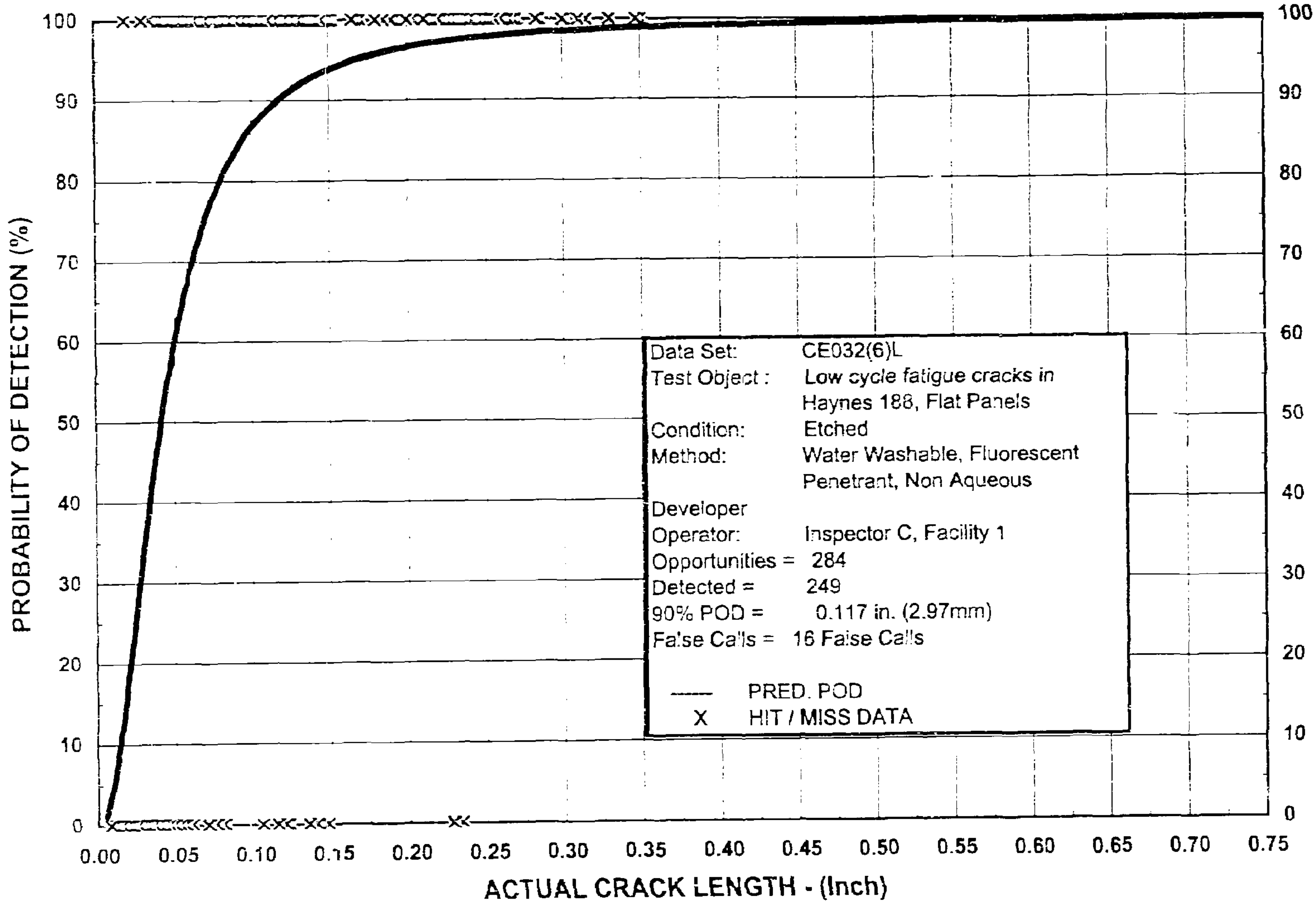
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE022(6)L
11/97 -CE022(6)L



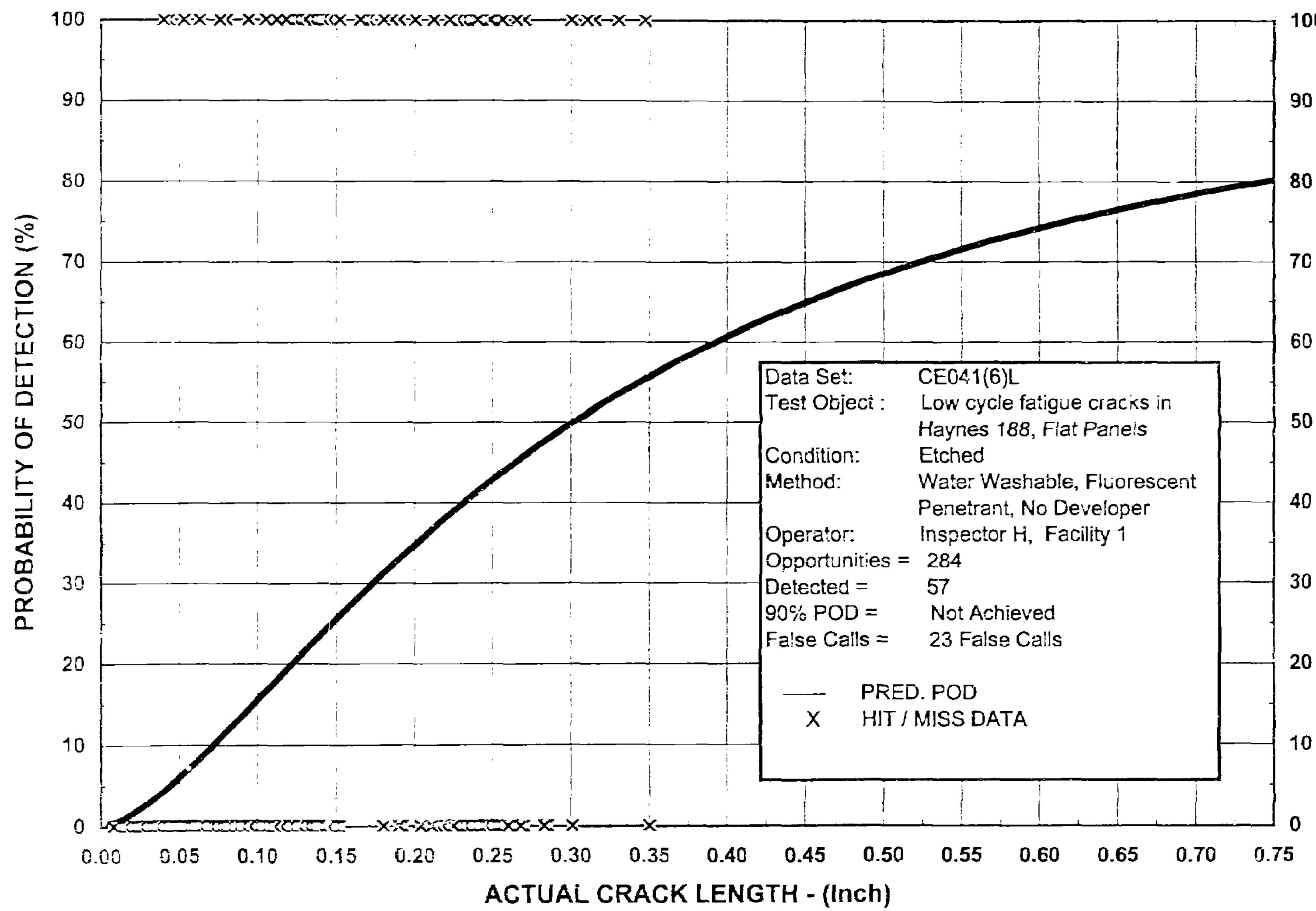
CE031(6)L
11/97 -CE031(6)L

**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer**



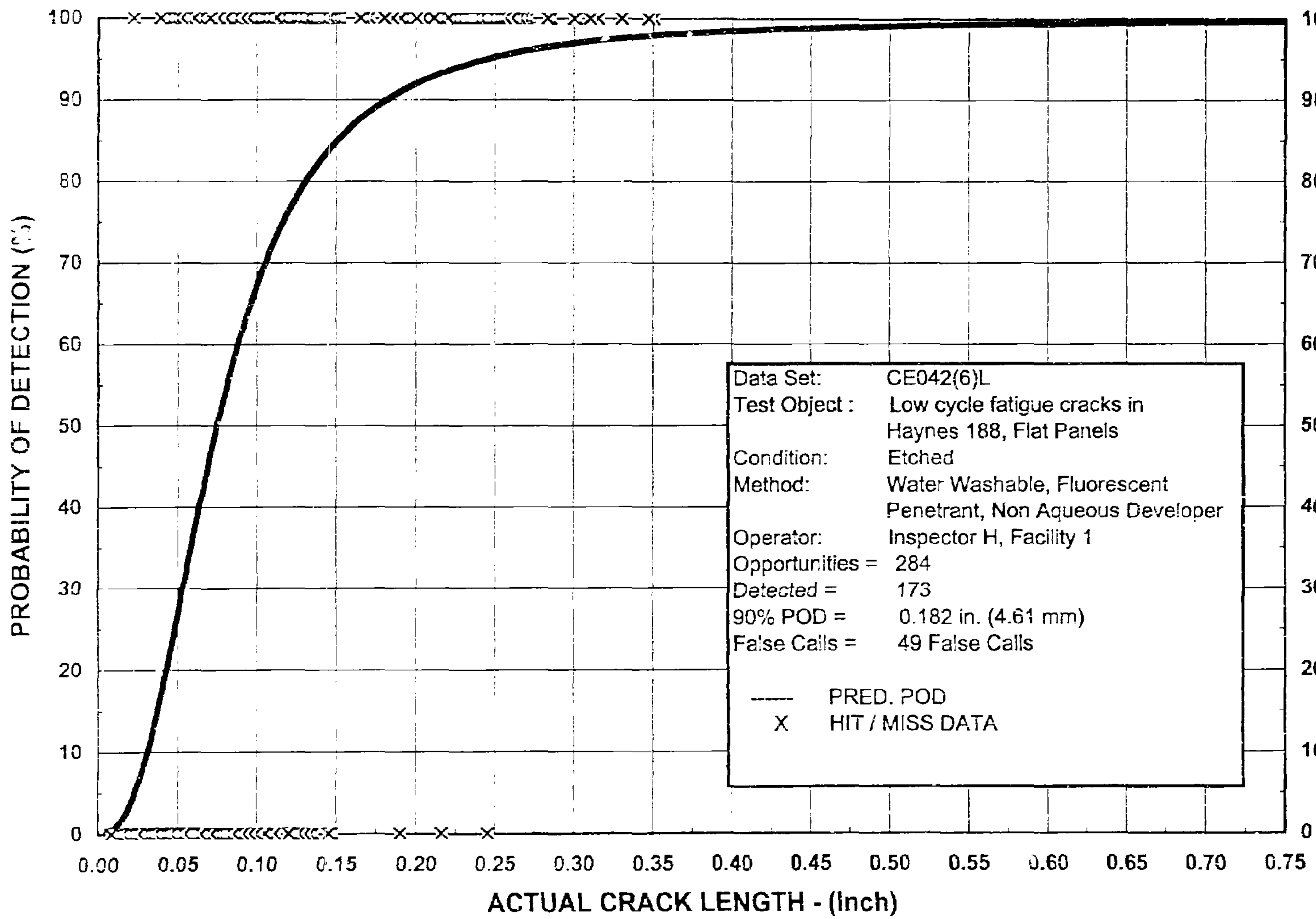
**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer**

CE032(6)L
11/97 -CE032(6)L



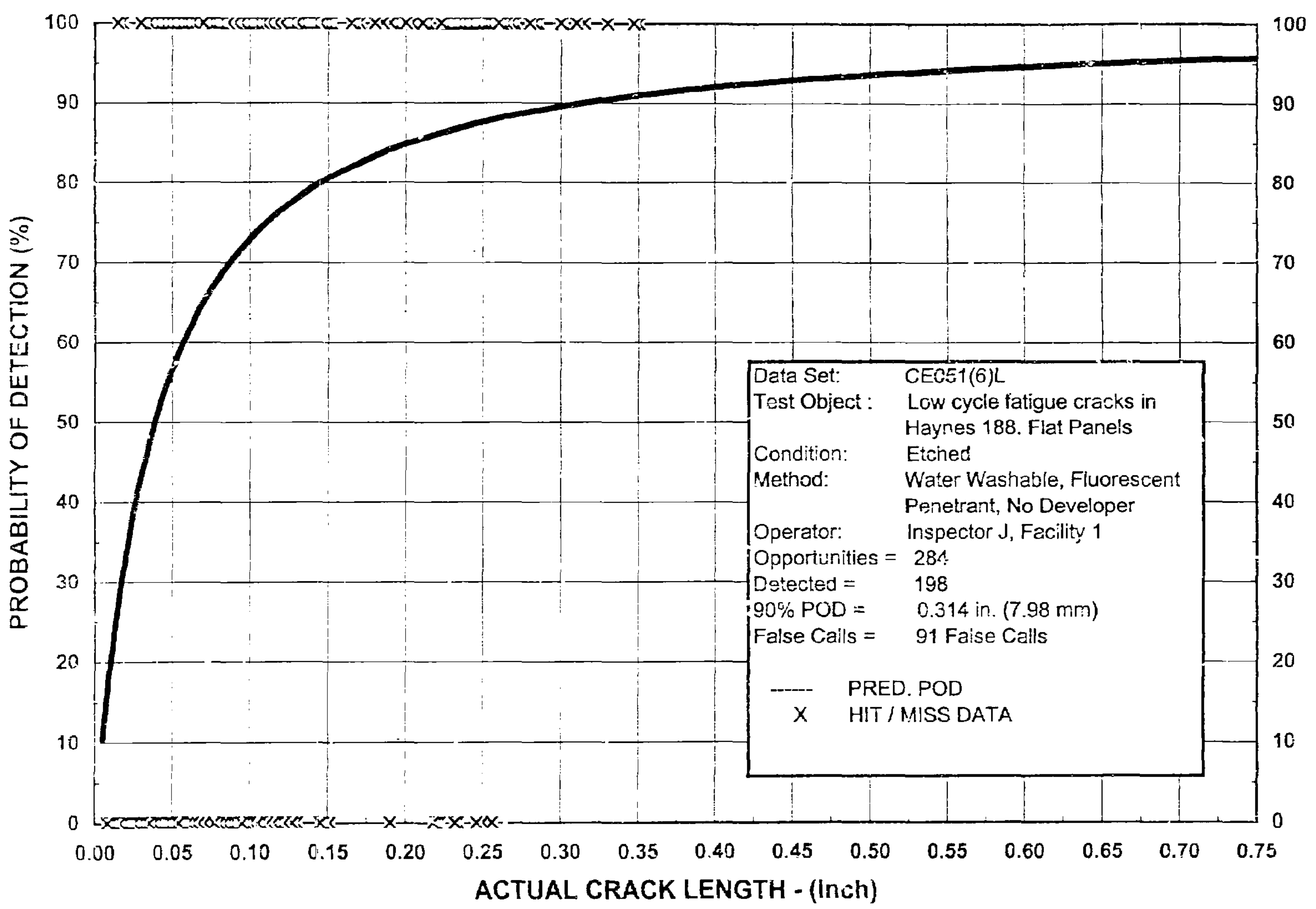
CE041(6)L
11'97 -CE041(6)L

**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer**



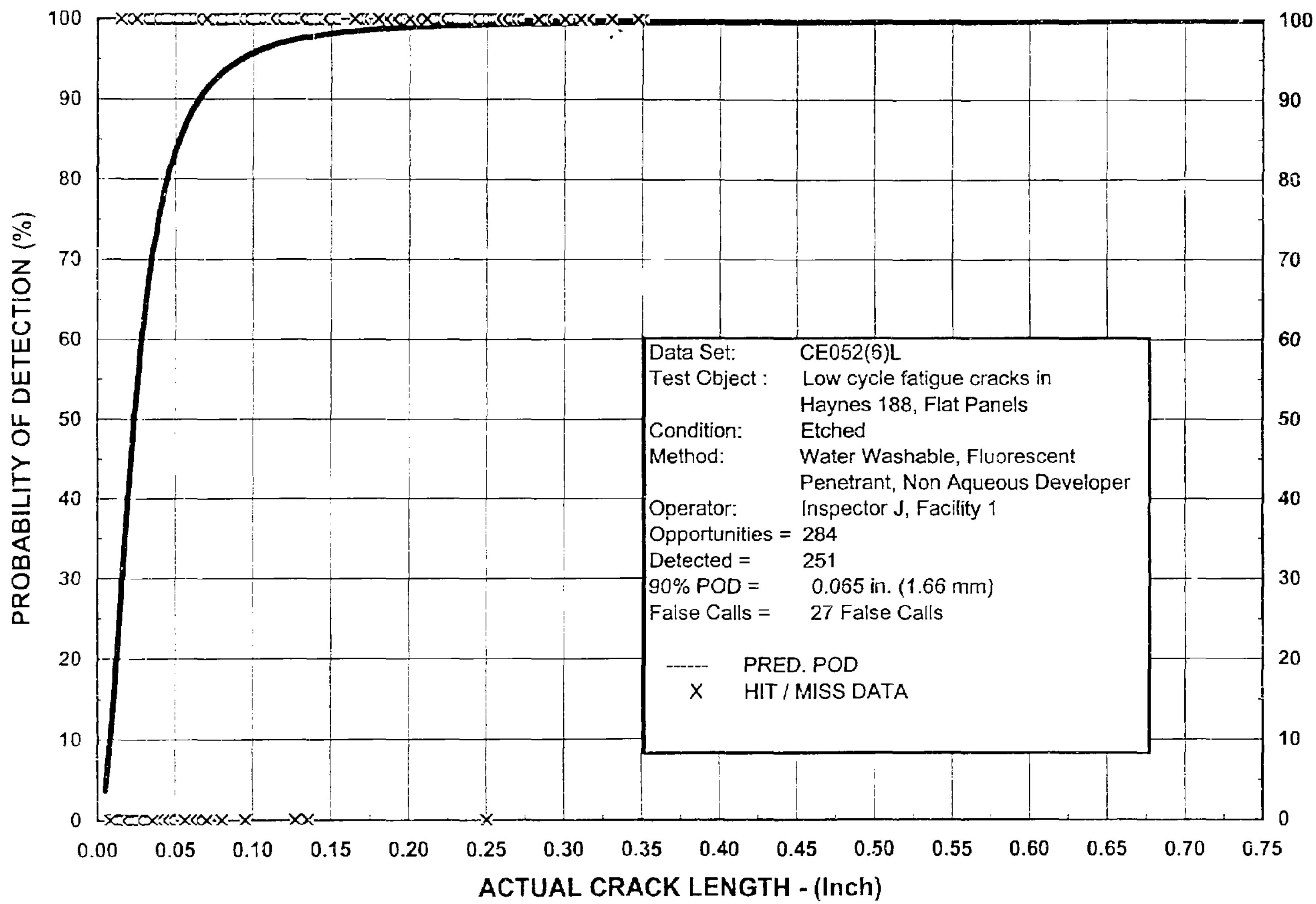
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE042(6)L
11/97 -CE042(6)L



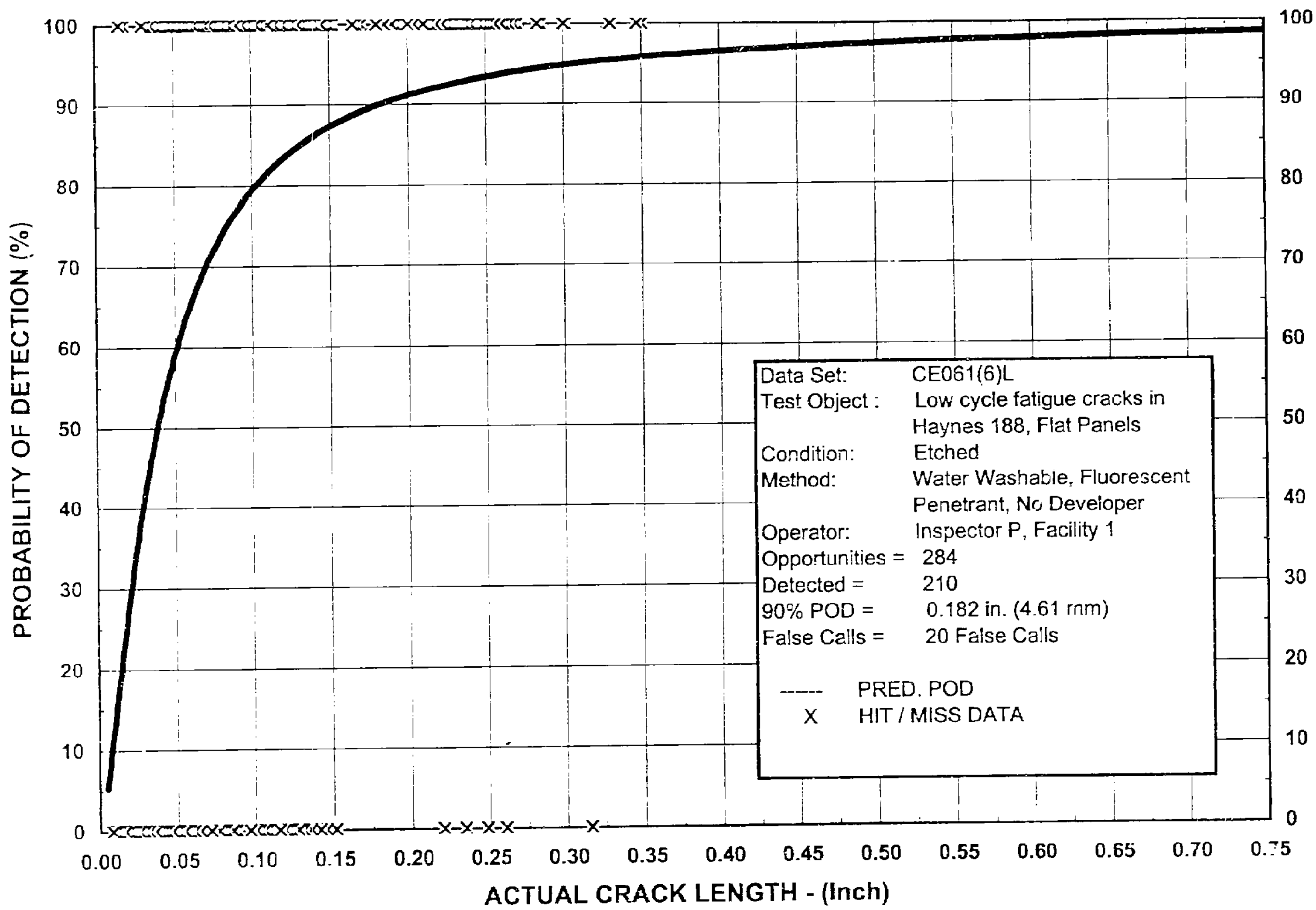
CE051(6)L
11/97 -CE051(6)L

Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Paneis,
No Developer



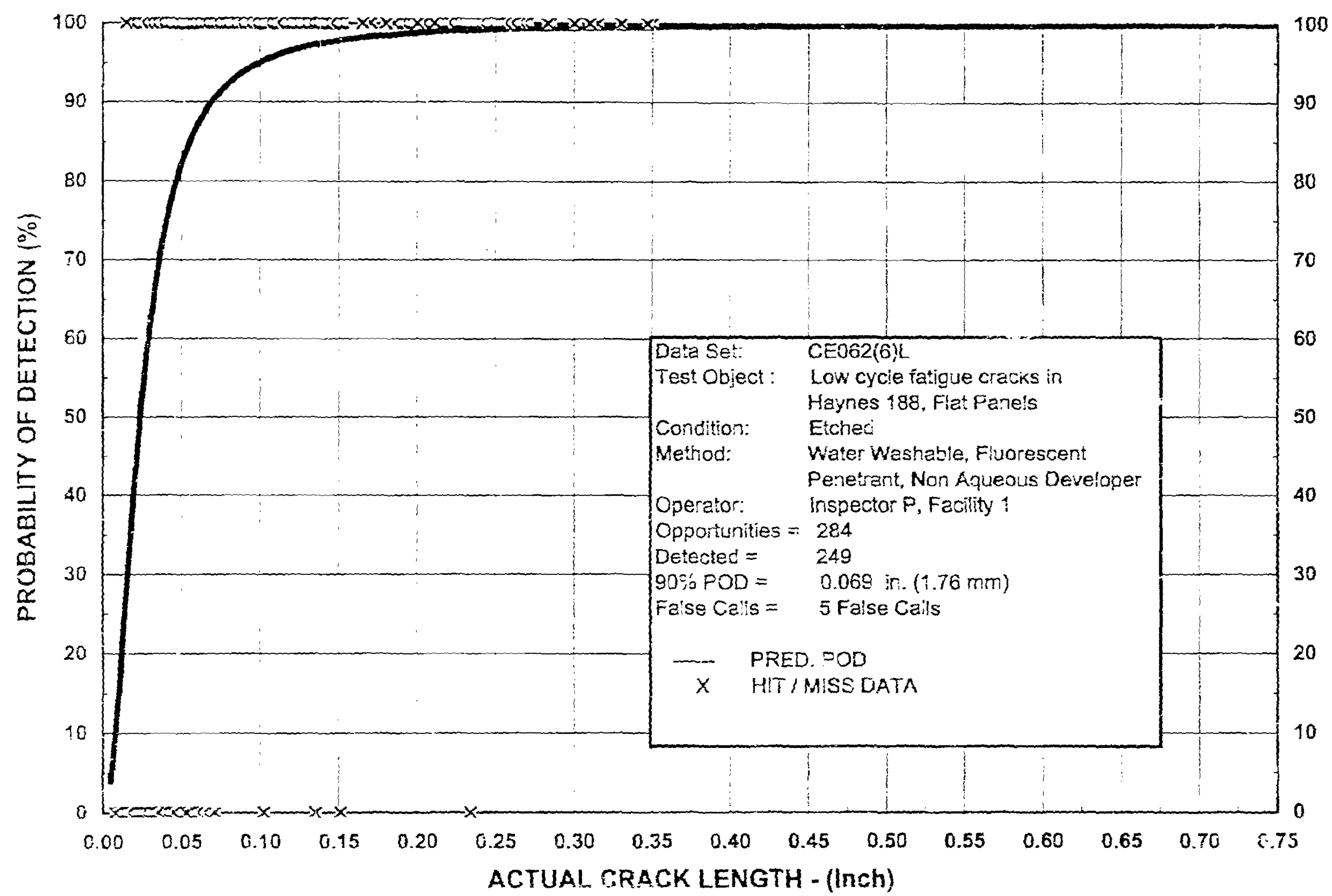
CE052(6)L
11/97 -CE052(6)L

**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer**



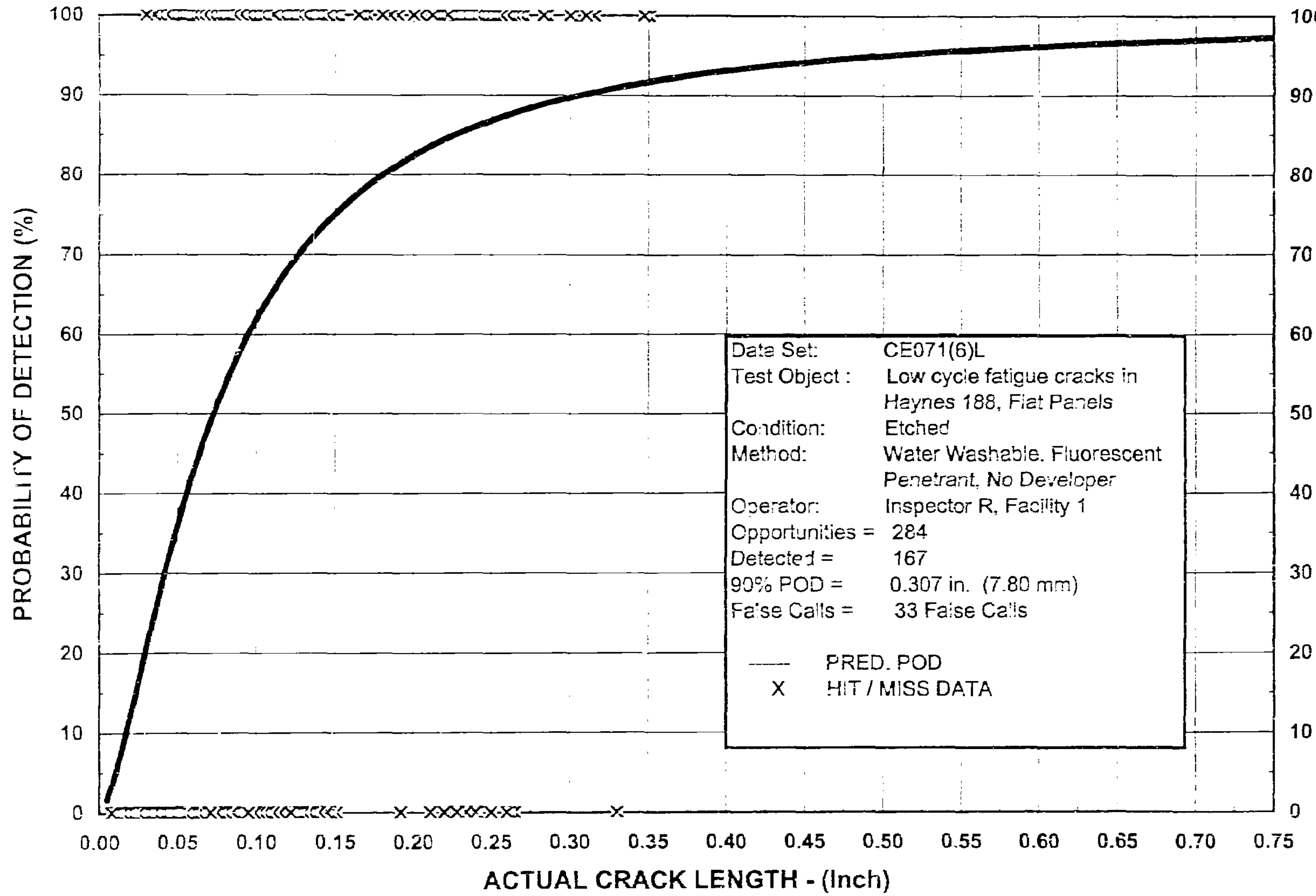
**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer**

CE061(6)L
11/97 -CE061(6)L



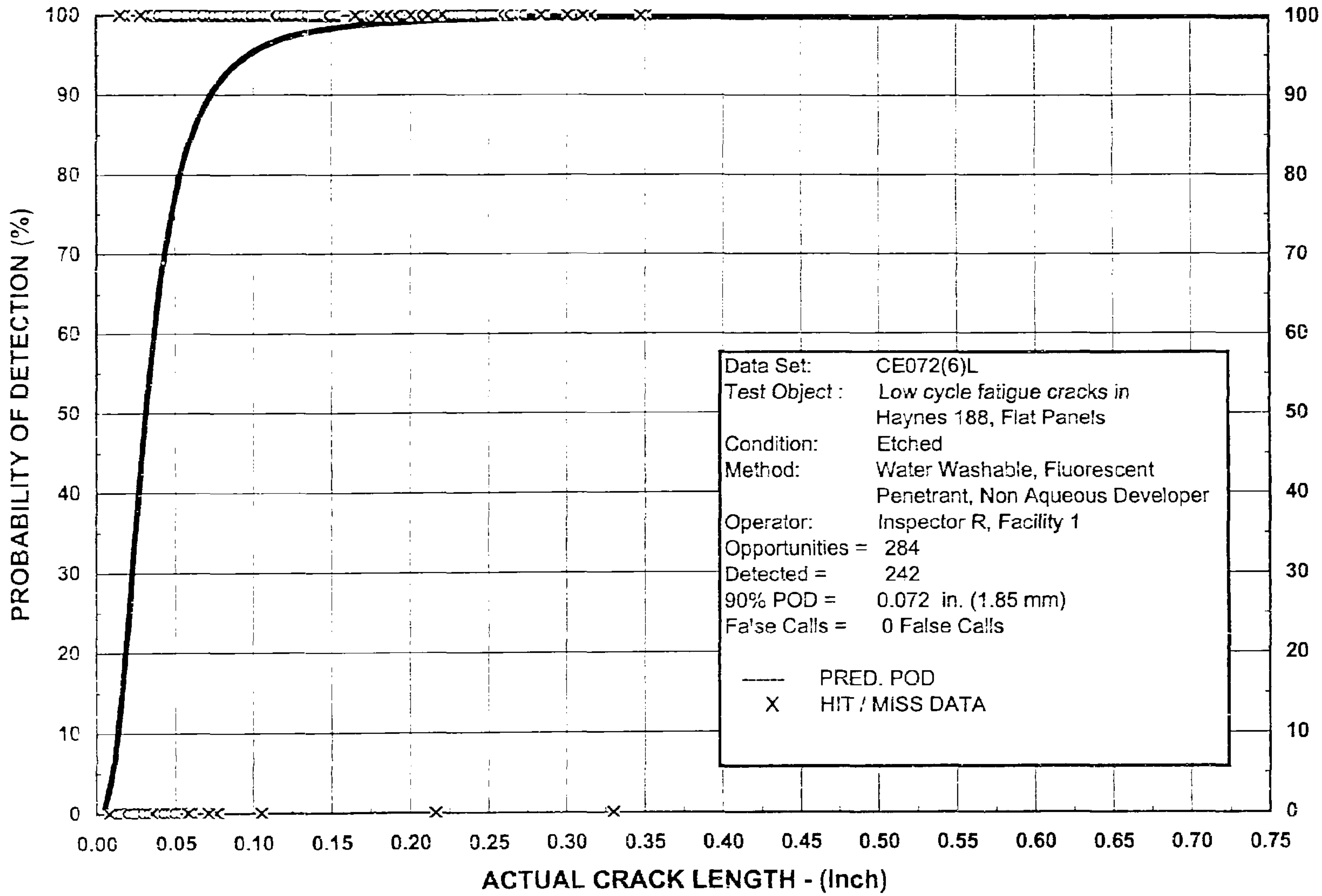
CE062(6)L
11/97 -CE062(6)L

Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer



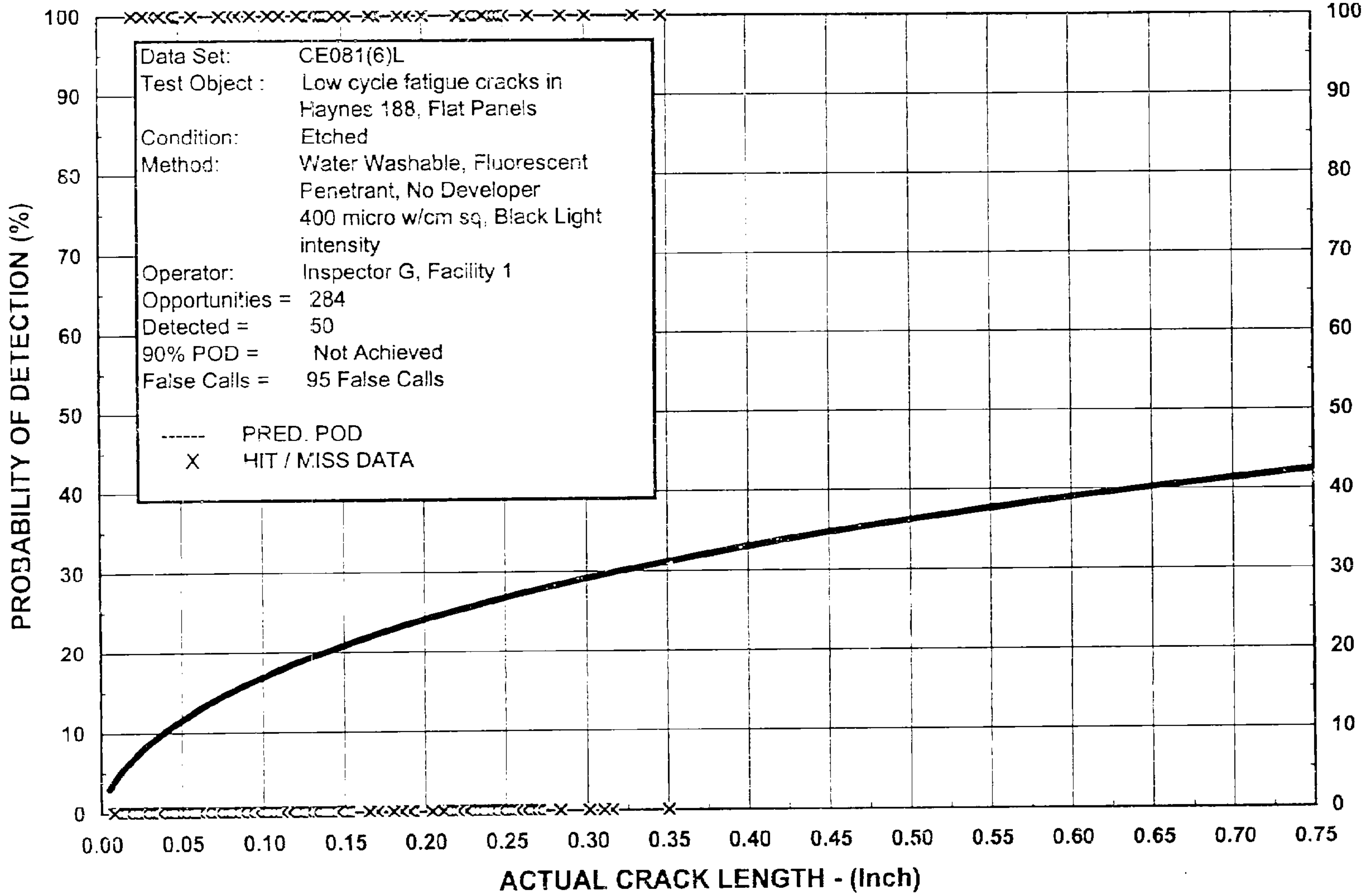
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE071(6)L
11/97 -CE071(6)L



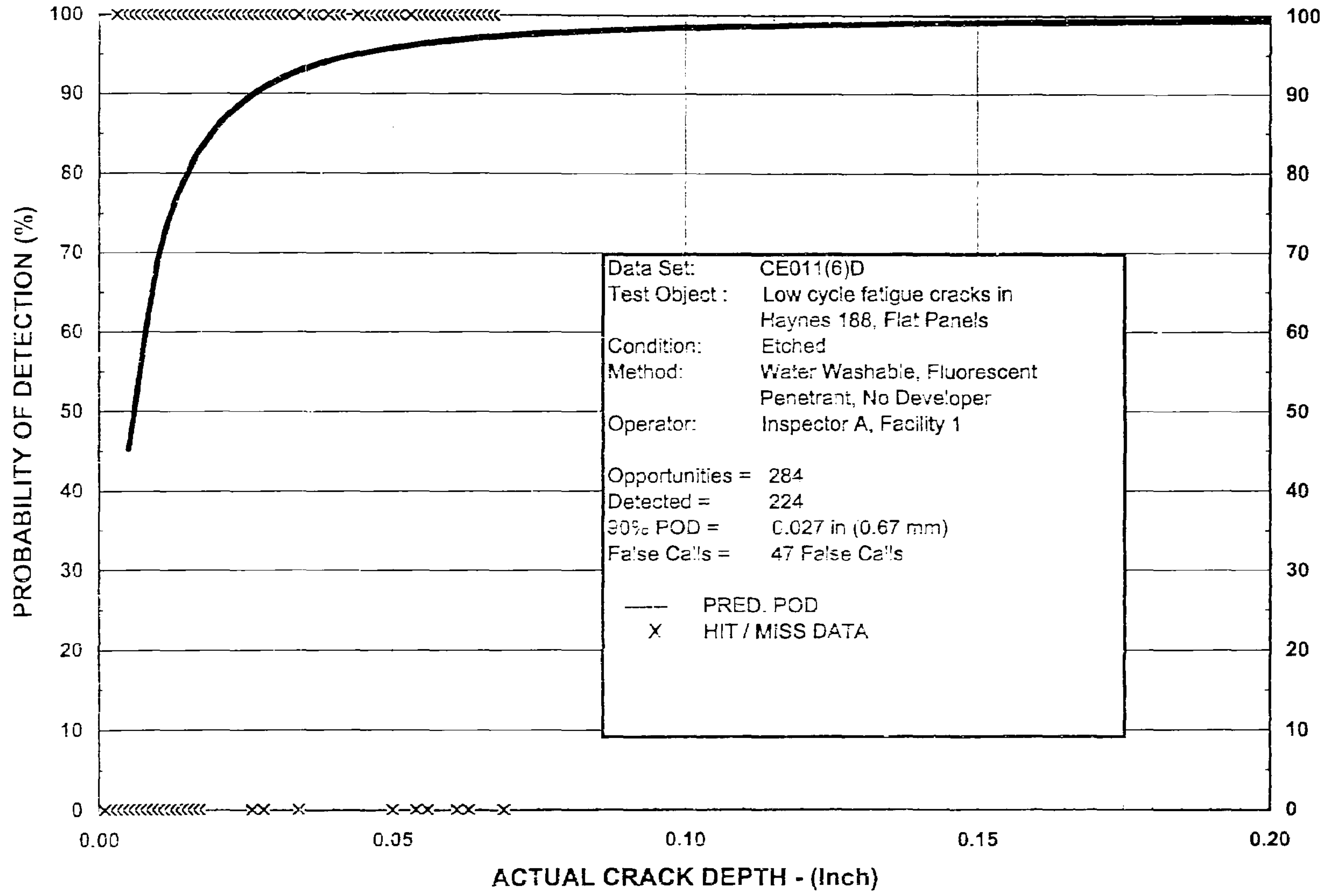
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE072(6)L
11/97 -CE072(6)L



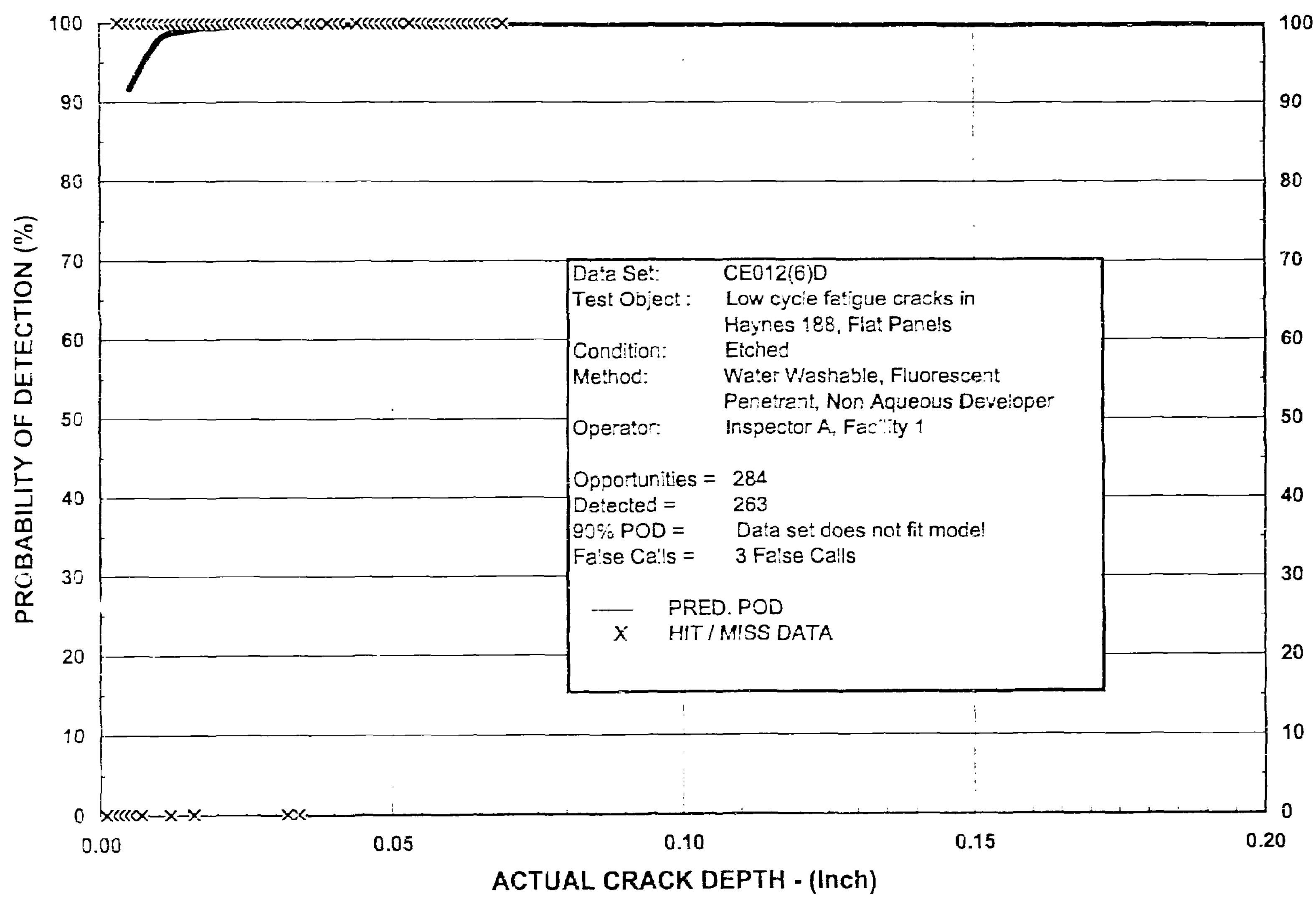
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer
with 400 microwatts / sq cm Black Light Intensity

CE081(6)L
11/97 -CE081(6)L



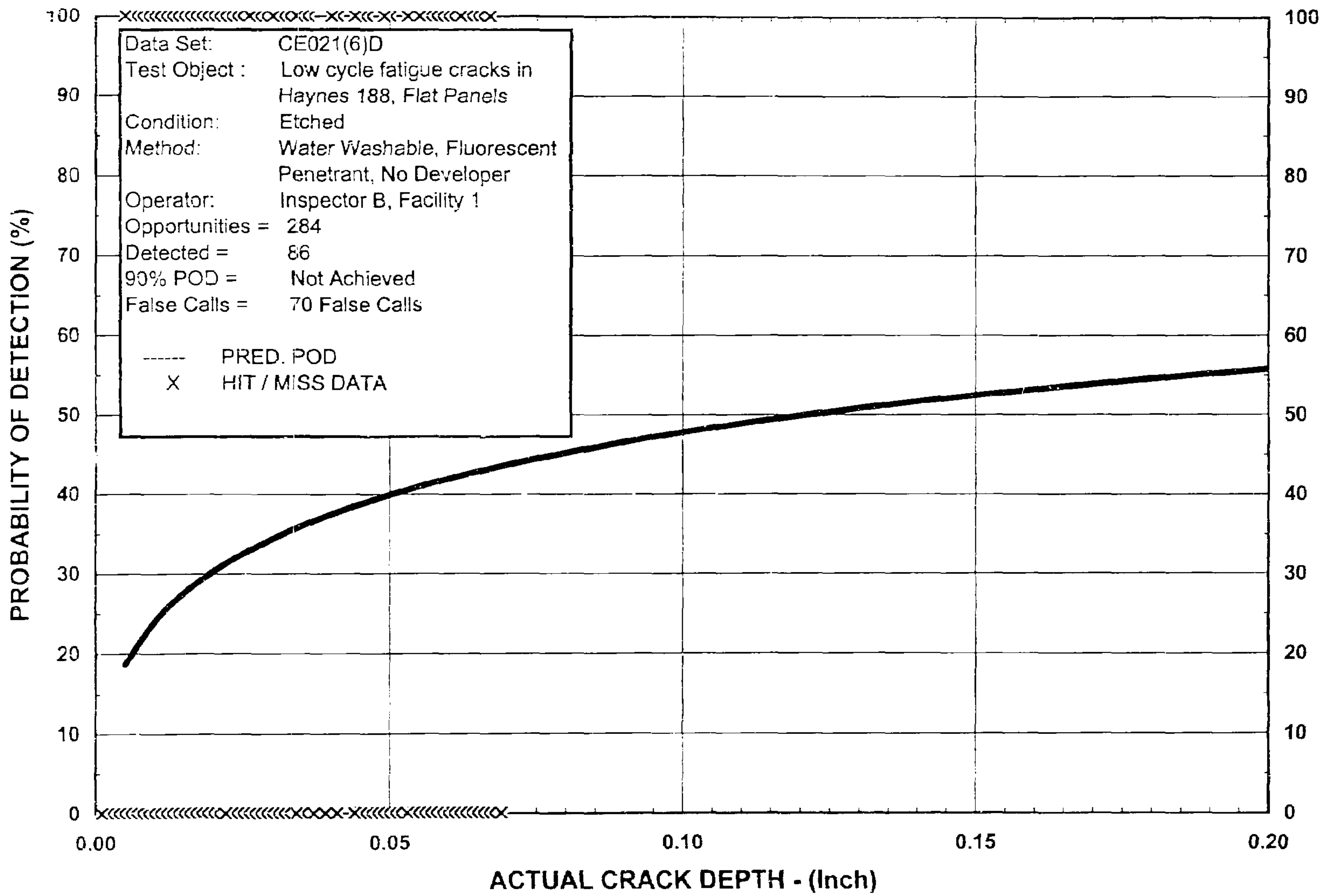
Water Washable,
Flucrescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE011(6)D
11/97 -CE011(6)D

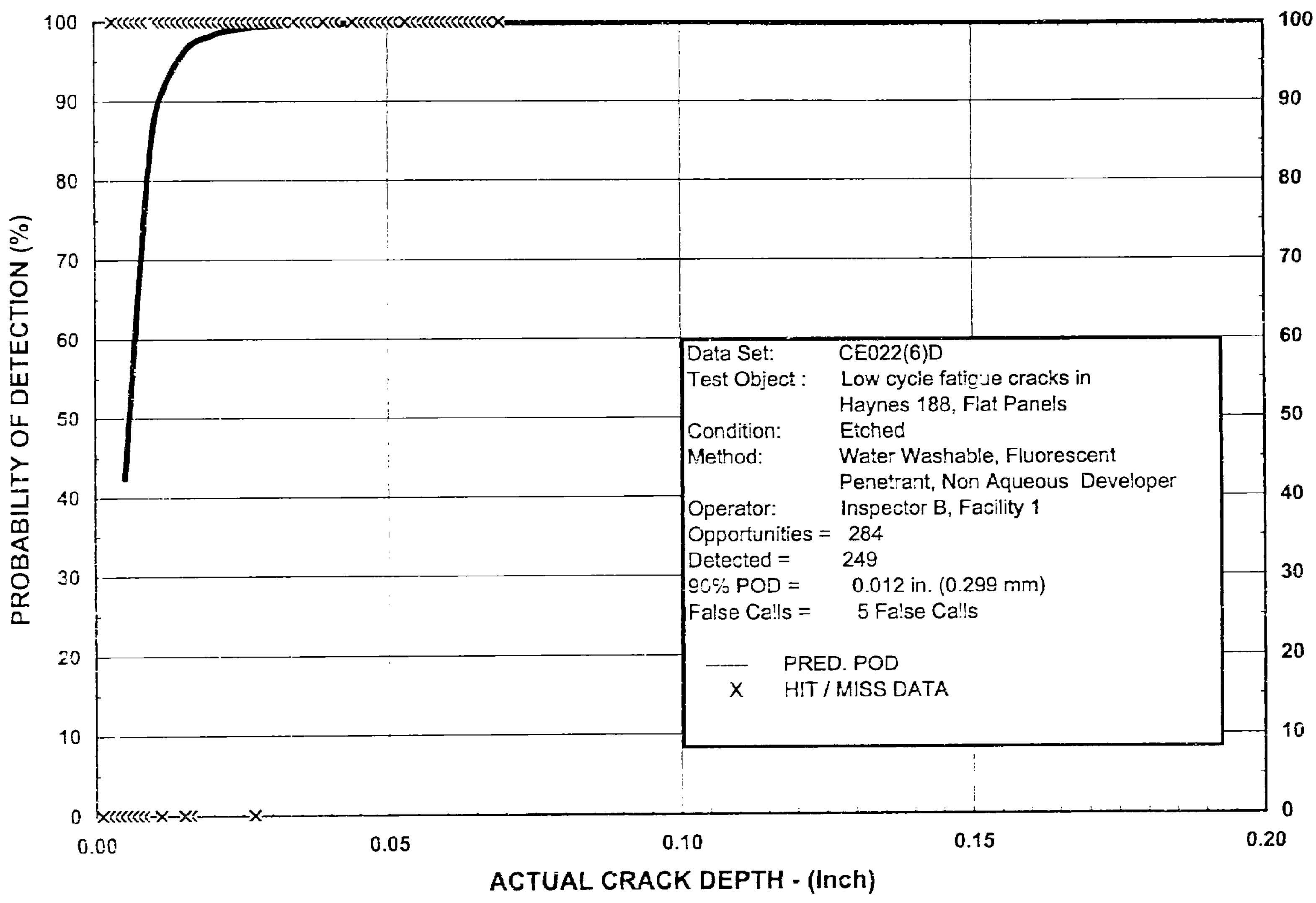


Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE012(6)D
11/97 -CE012(6)D

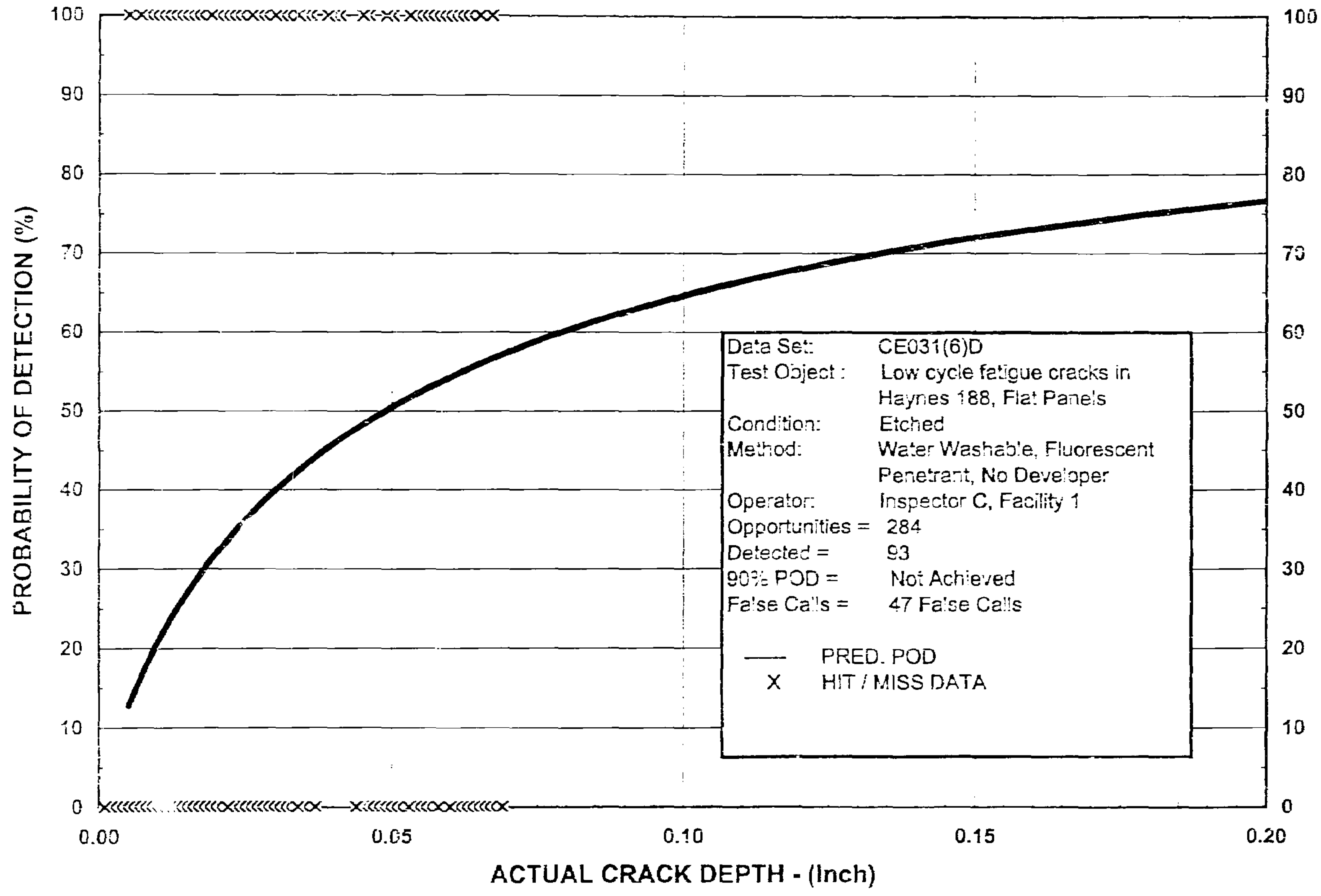


Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer



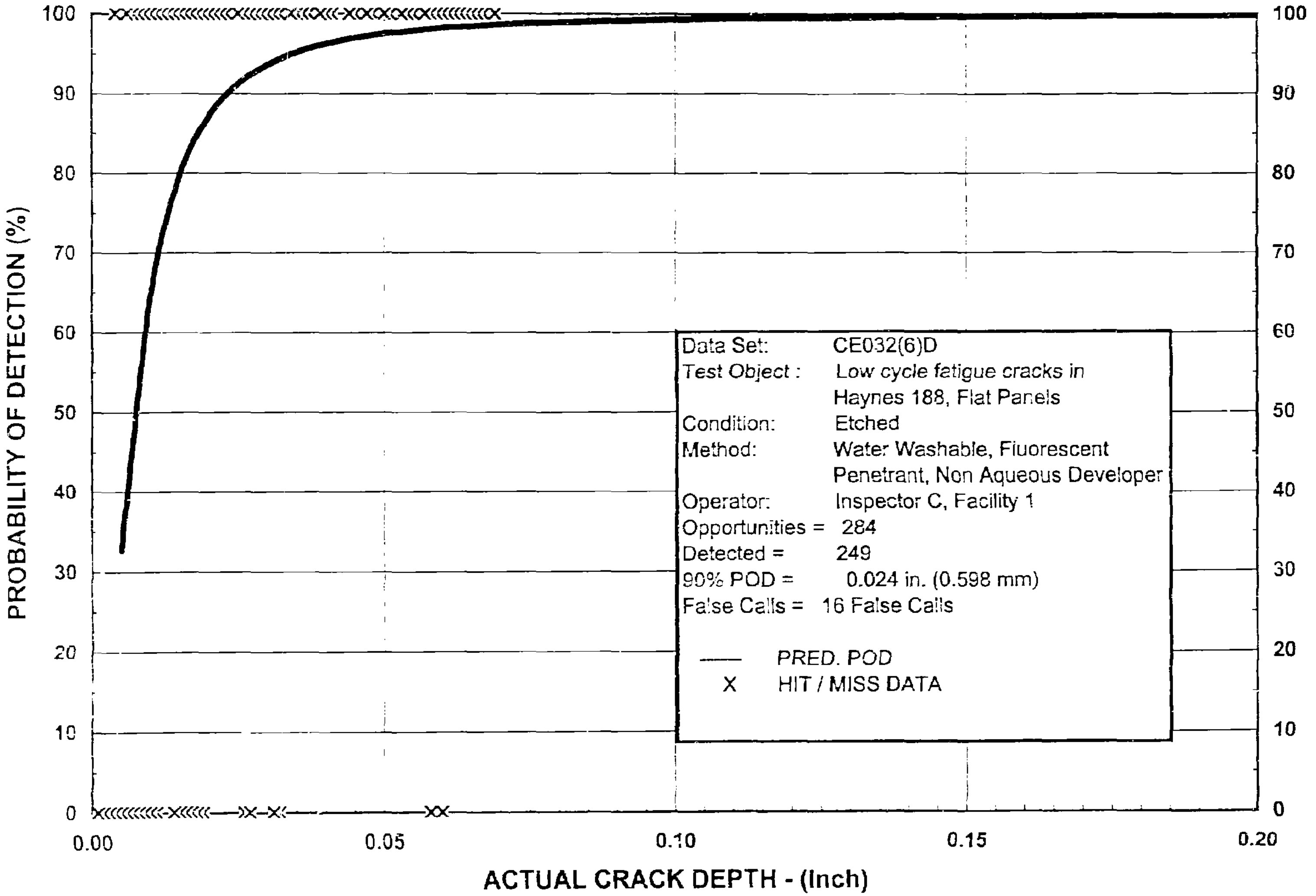
**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer**

CE022(6)D
11/97 -CE022(6)D



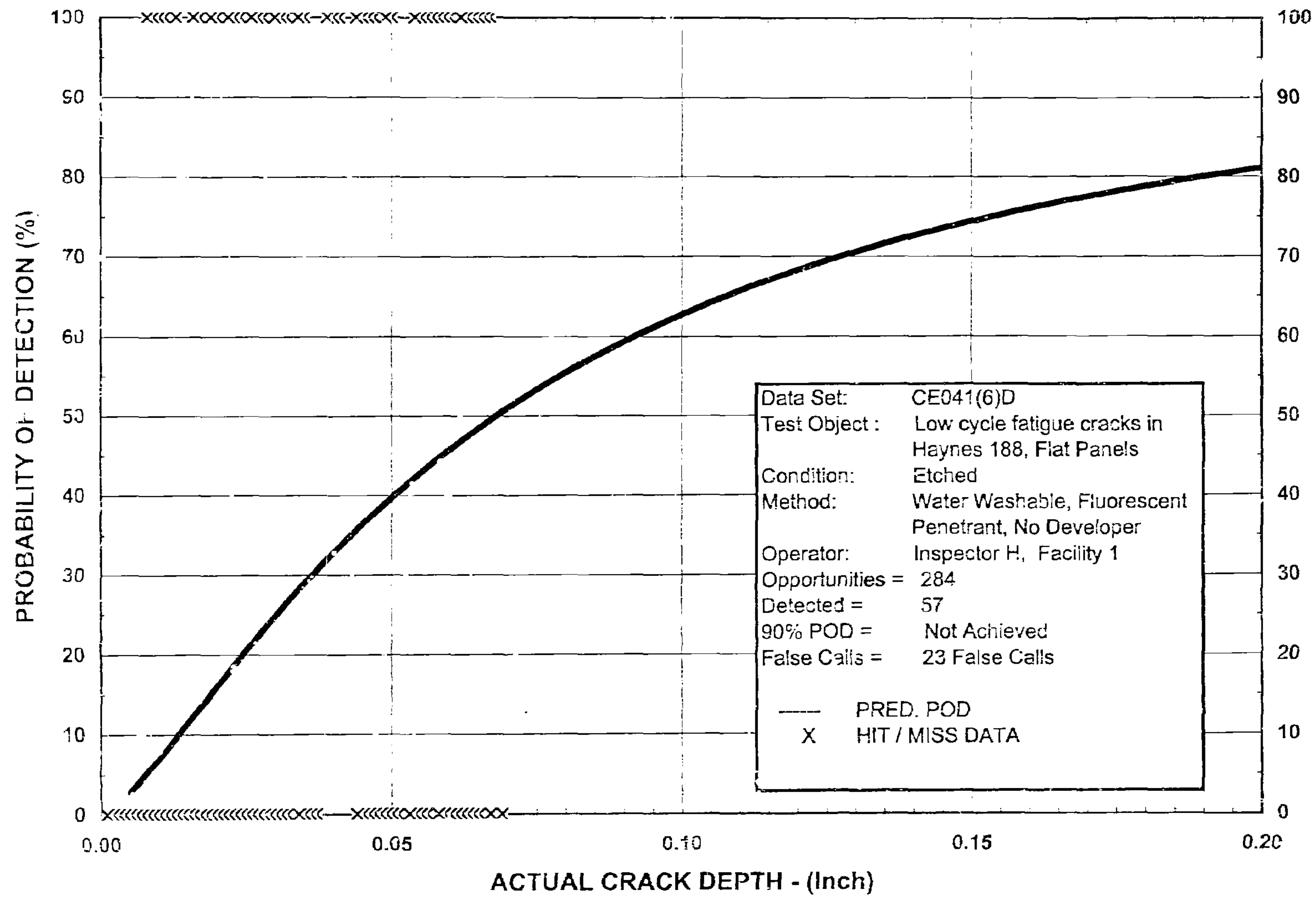
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE031(6)D
11/97 -CE031(6)D



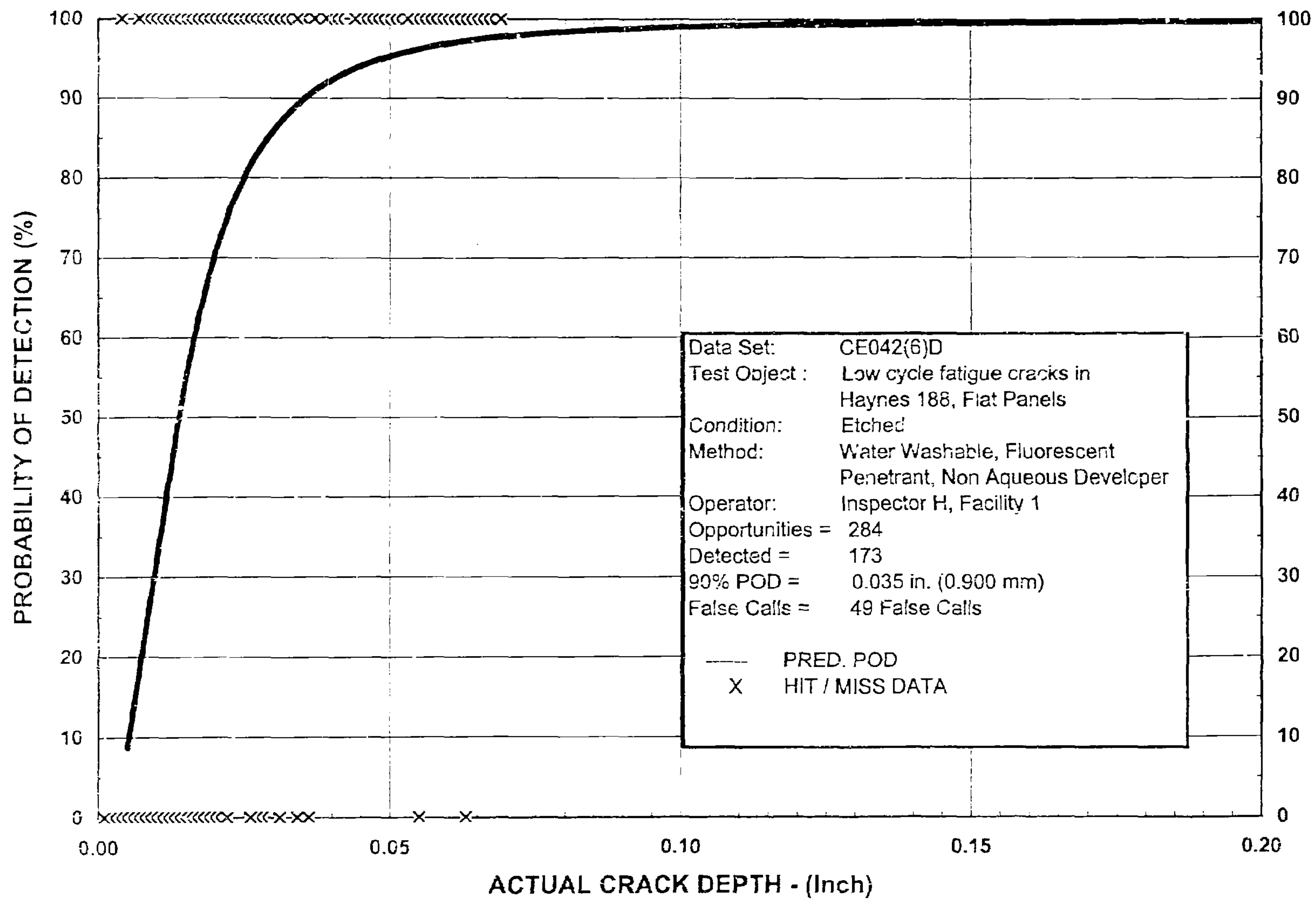
CE032(6)D
11/97 -CE032(6)D

Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer



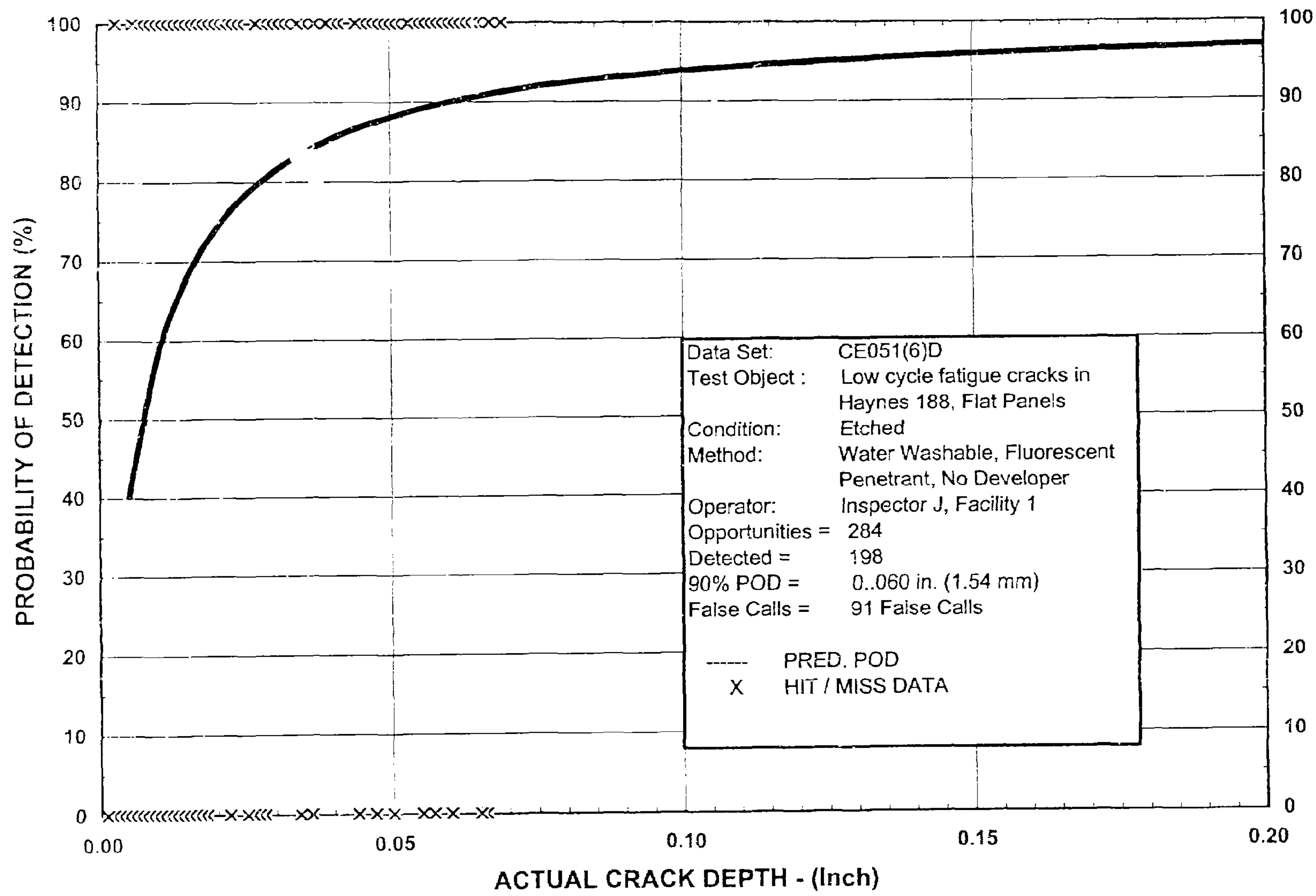
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE041(6)D
11/97 -CE041(6)D



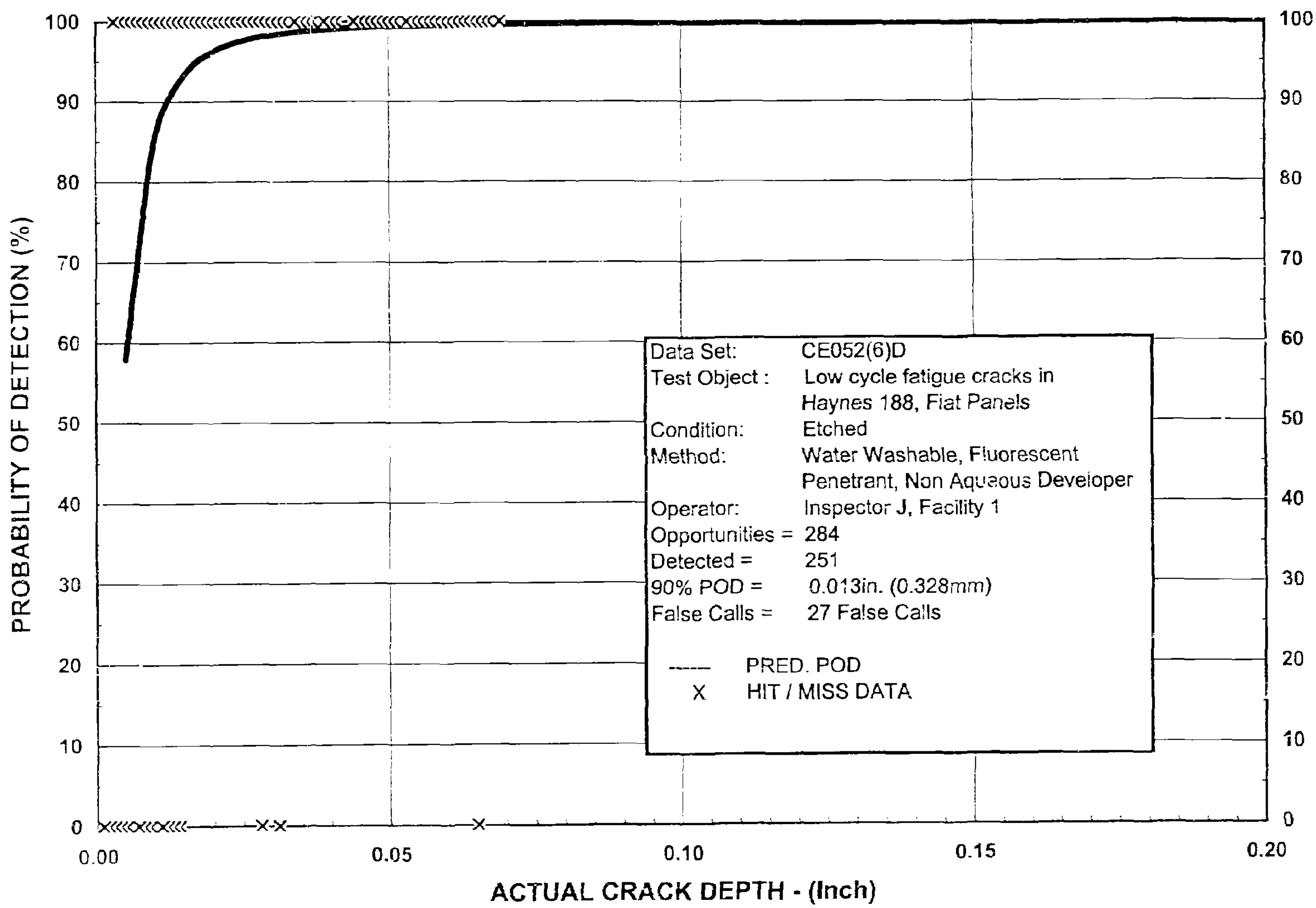
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

CE042(6)D
11/97 -CE042(6)D



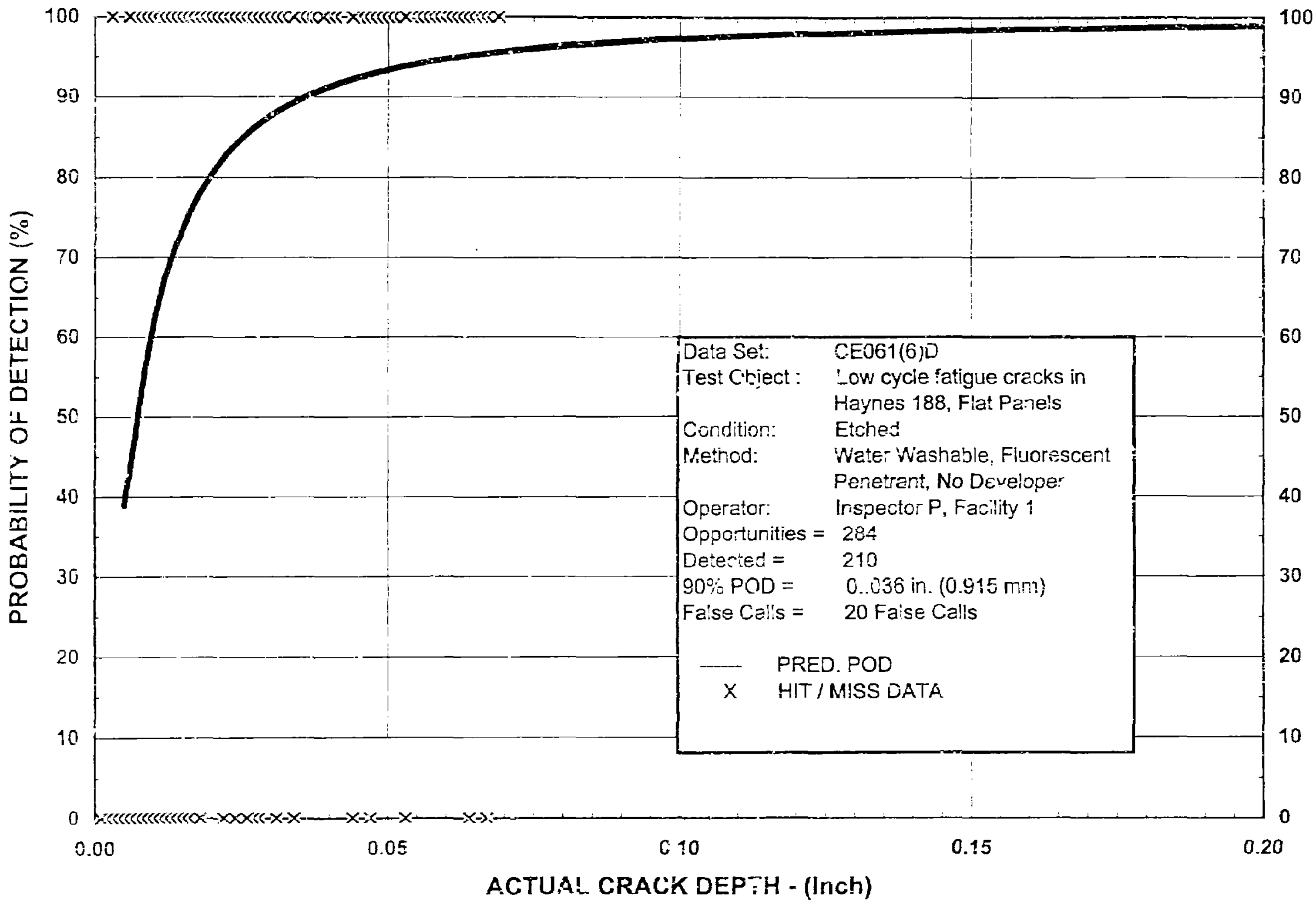
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

CE051(6)D
11/97 -CE051(6)D



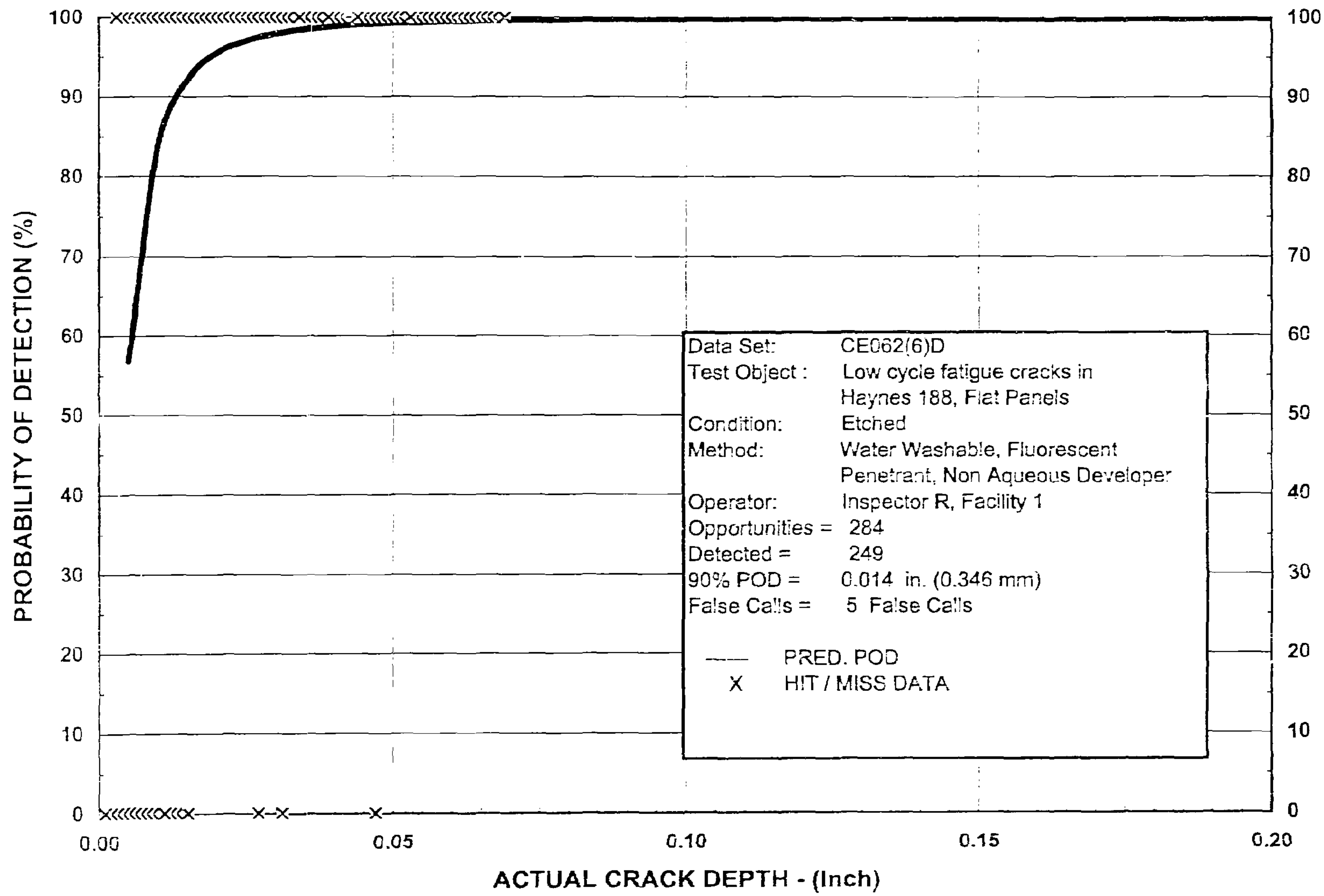
CE052(6)D
11/97 -CE052(6)D

Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer



Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer

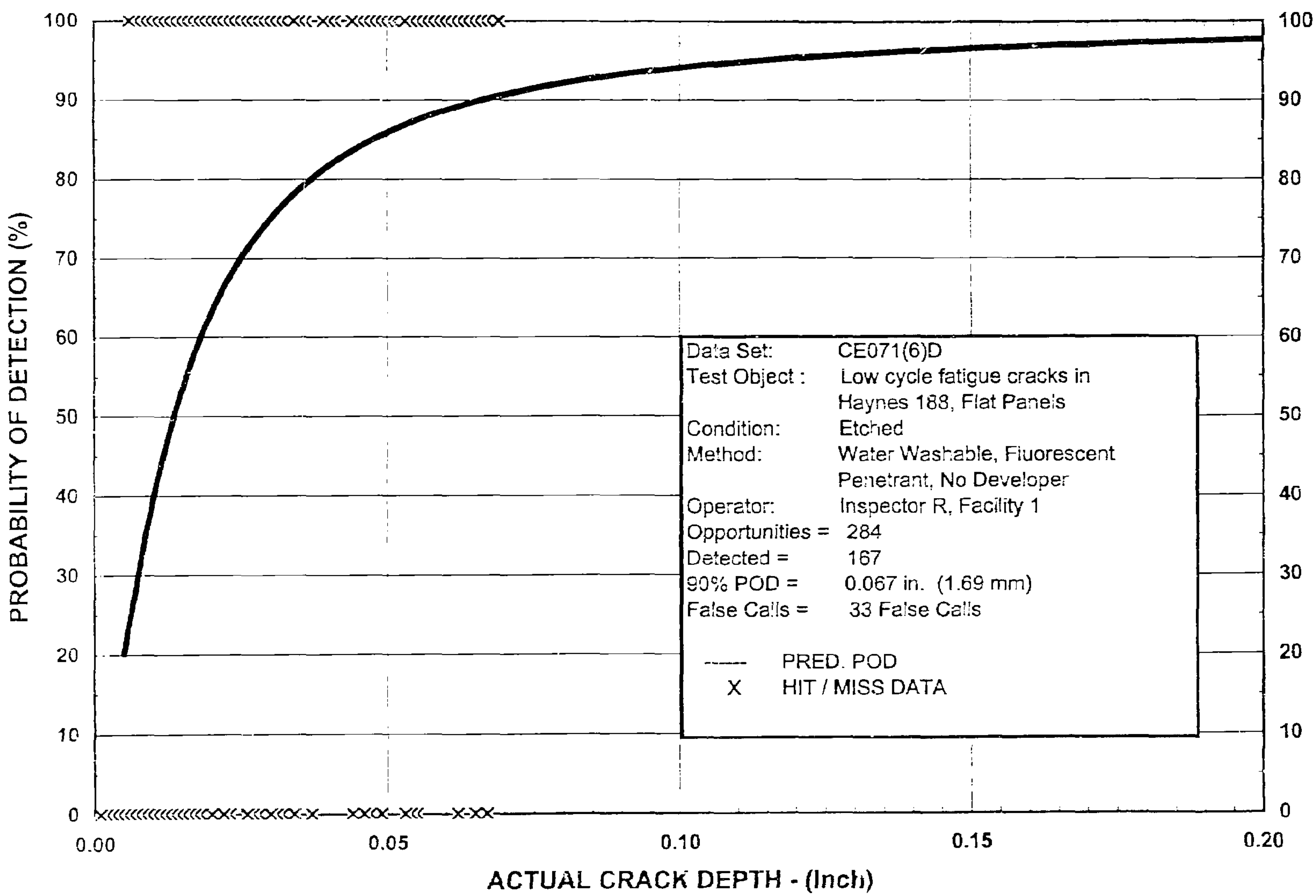
CE061(6)D
11/97 -CE061(6)D



Water Washable, Fluorescent Penetrant on Haynes 188 Flat Panels, Non Aqueous Wet Developer

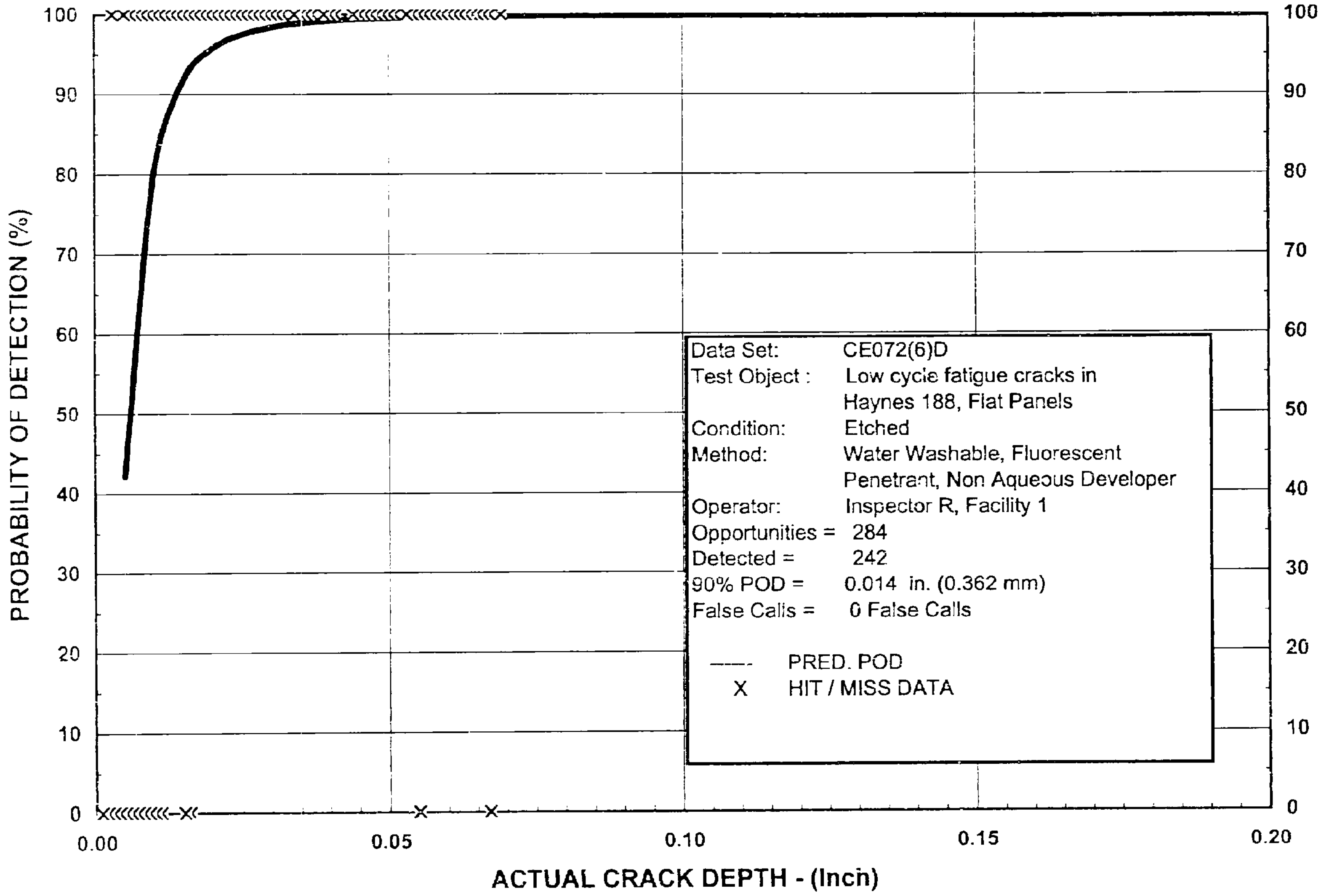
CE062(6)D

11/97 -CE062(6)D



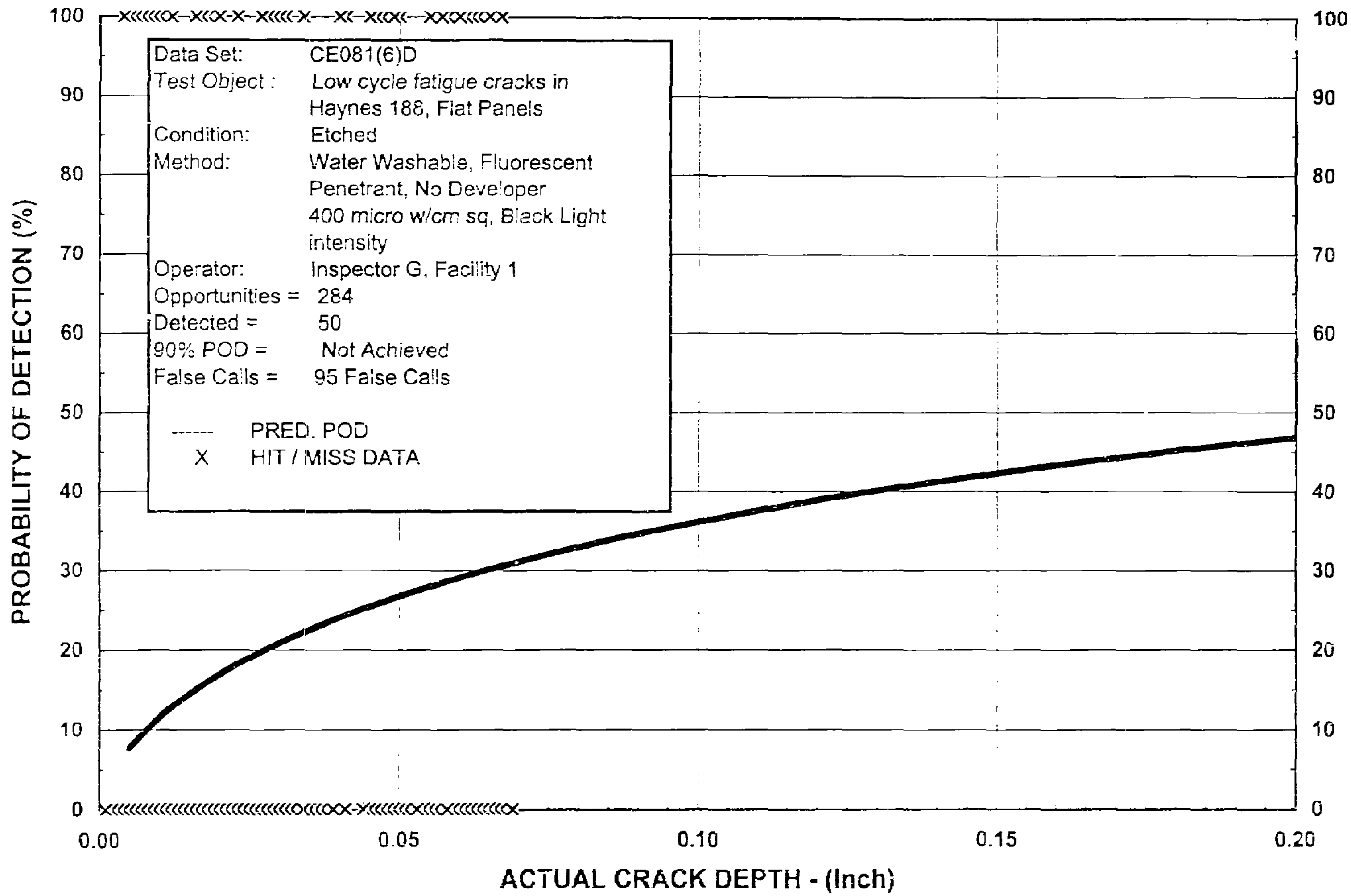
CE071(6)D
11/97 -CE071(6)D

Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer



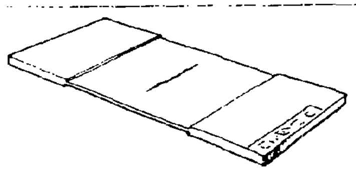
Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
Non Aqueous Wet Developer

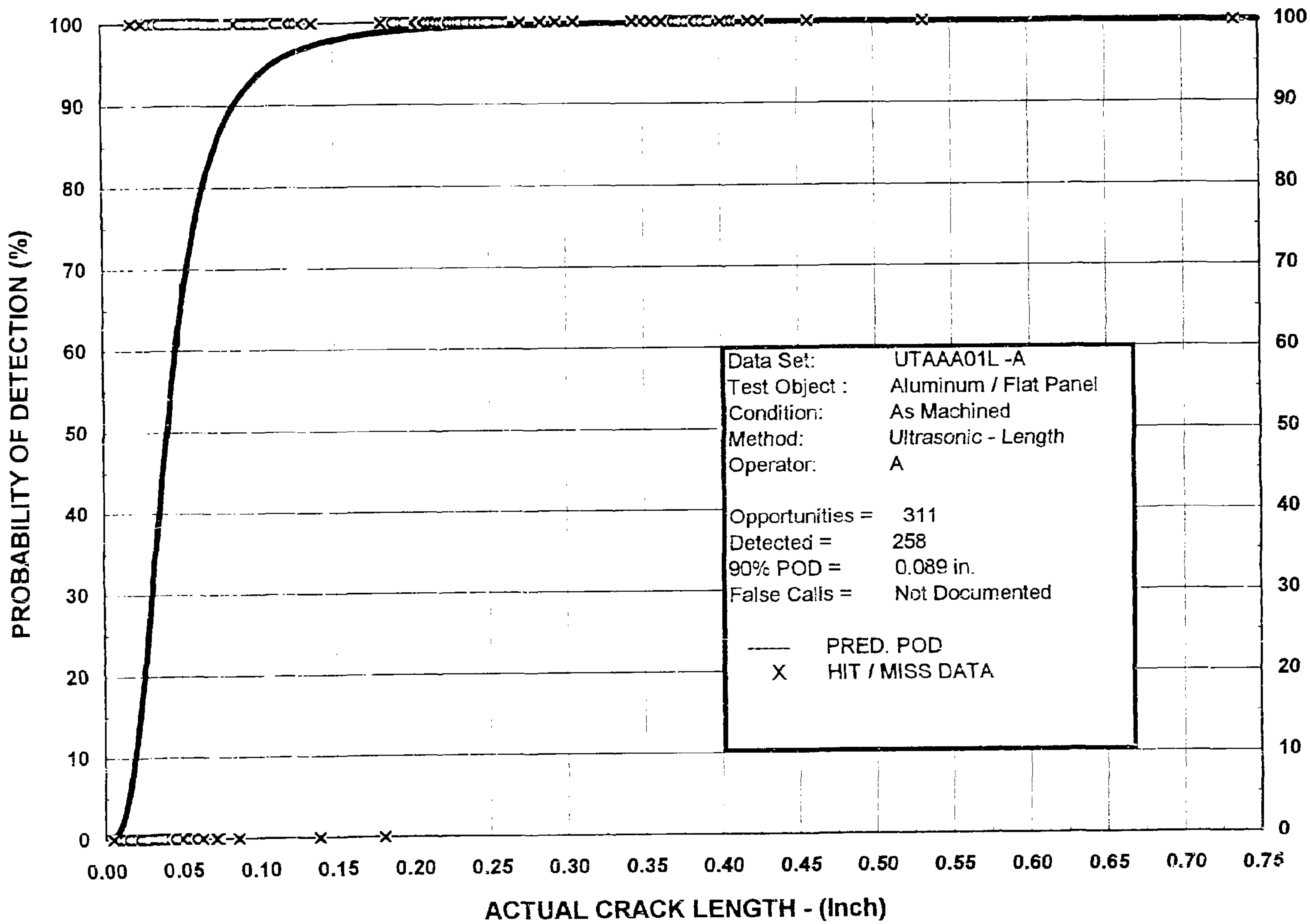
CE072(6)D
11/97 -CE072(6)D



CE081(6)D
11/97 -CE081(6)D

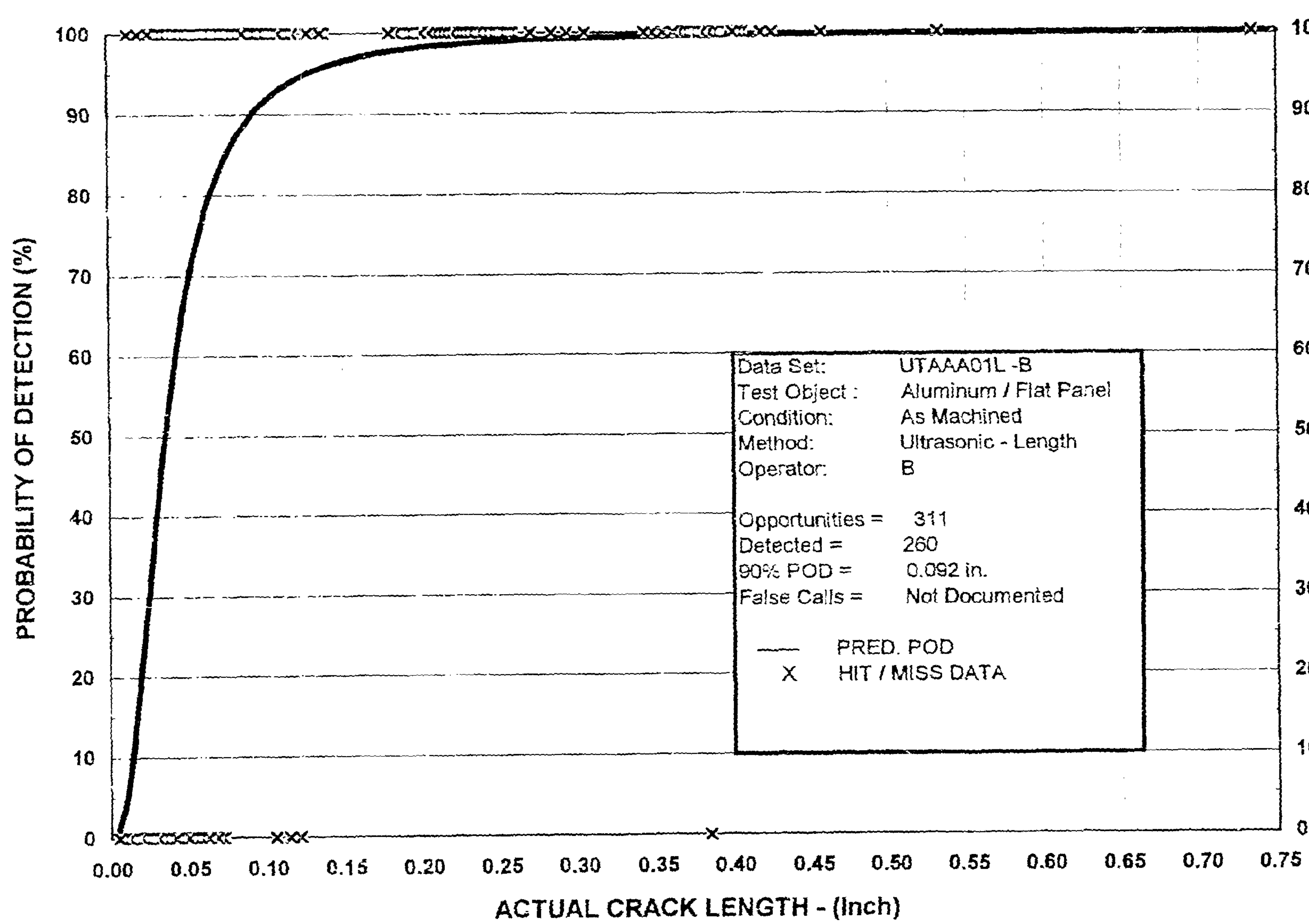
**Water Washable,
Fluorescent Penetrant on Haynes 188 Flat Panels,
No Developer
with 400 microwatts / sq cm Black Light Intensity**

UT - 01 (1) CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	Ultrasonic Surface Wave
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Ultrasonic Surface Wave - Immersion at 10MHz
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	*2219 Aluminum T-87*
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	-01."As Machined", -02."After Etch", -03."After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Immersion - C-scan recording
DATA SET IDENTIFIER:	UTAAA01L-A.B.C; UTAAA02L-A.B.C; UTAAA03L-A.B.C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	311 / 306 Cracks (5 cracks lost in proof test)
DETECTED:	UTAAA01L-A= 258, B= 260, C= 254; 02L-A= 252, B= 275, C= 274; 03L-A= 282, B= 284, C= 260
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the *National Aeronautics Administration* (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp. San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.
	90% POD Length - "AS MACHINED" "AFTER ETCH" "AFTER PROOF"
	A= 0.089 in. A= 0.167 in. A= 0.051 in.
	B= 0.092 in. B= 0.123 in. B= 0.034 in.
	C= 0.088 in. C= 0.086 in. C= 0.091 in.



UT - 01 (1) - CRACK LENGTH
6/95

UTAAA01L-A
Aluminum - Flat Plate

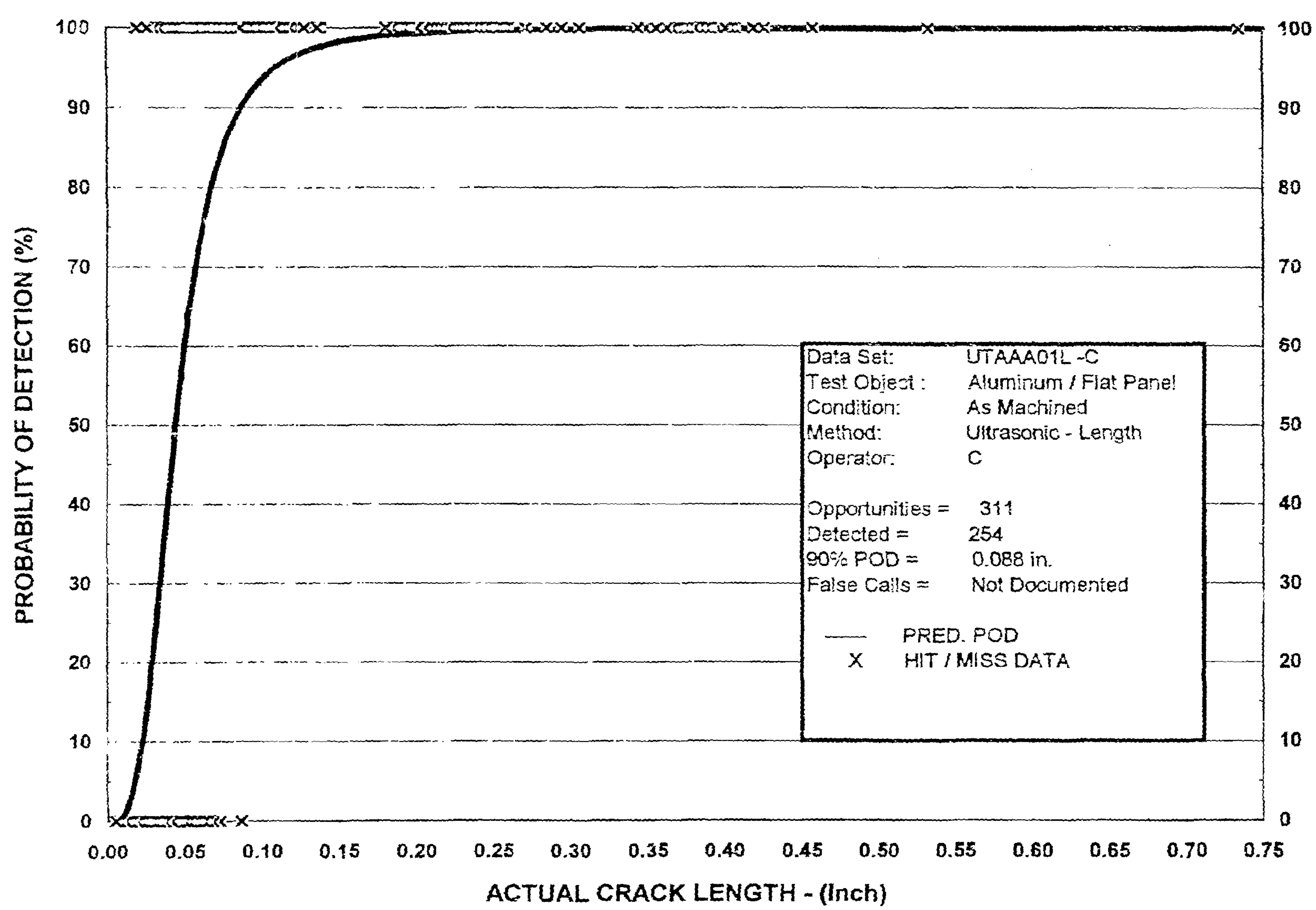


UT - 01 (1) CRACK LENGTH

6/95

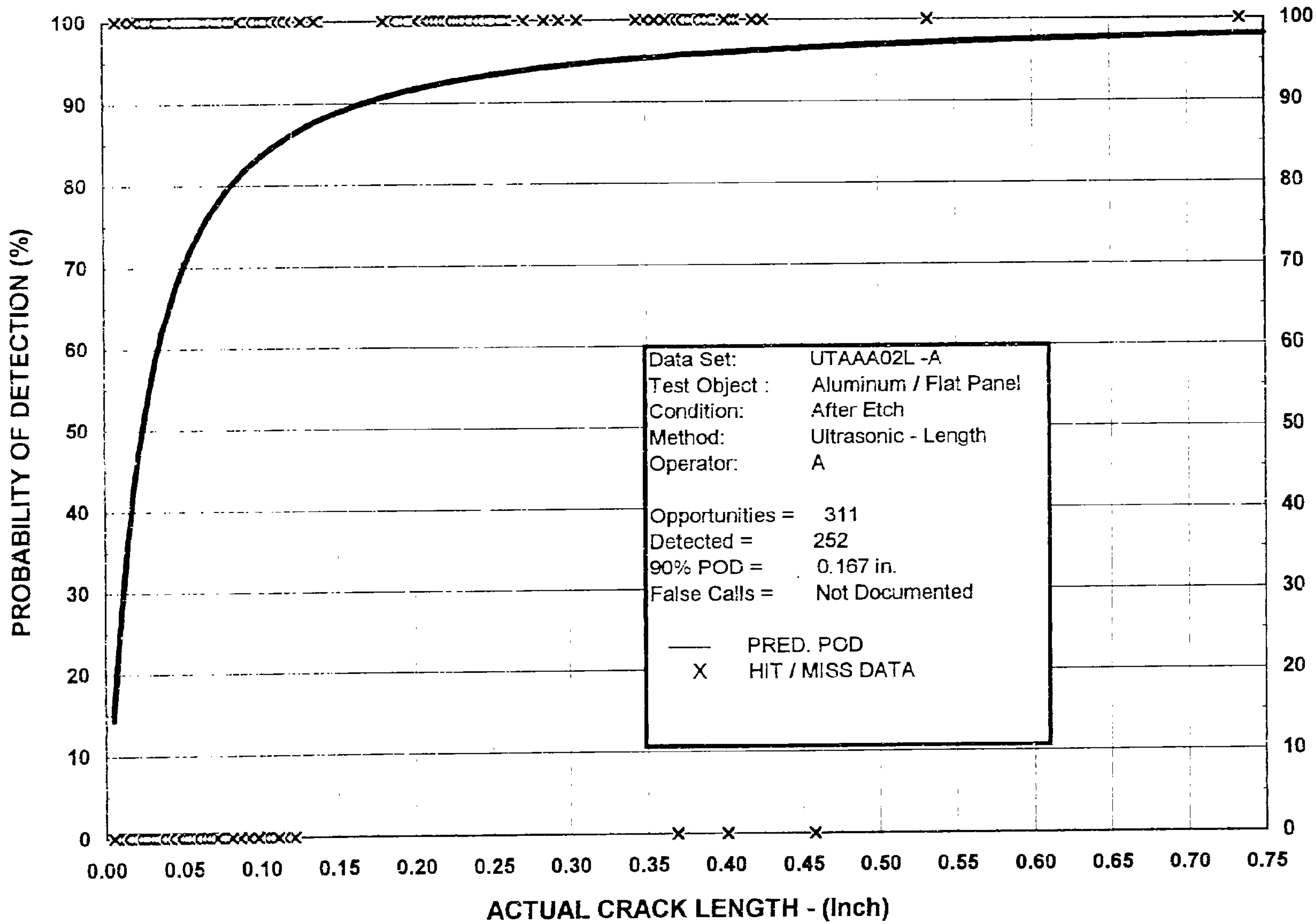
UTAAA01L-B

Aluminum - Flat Plate



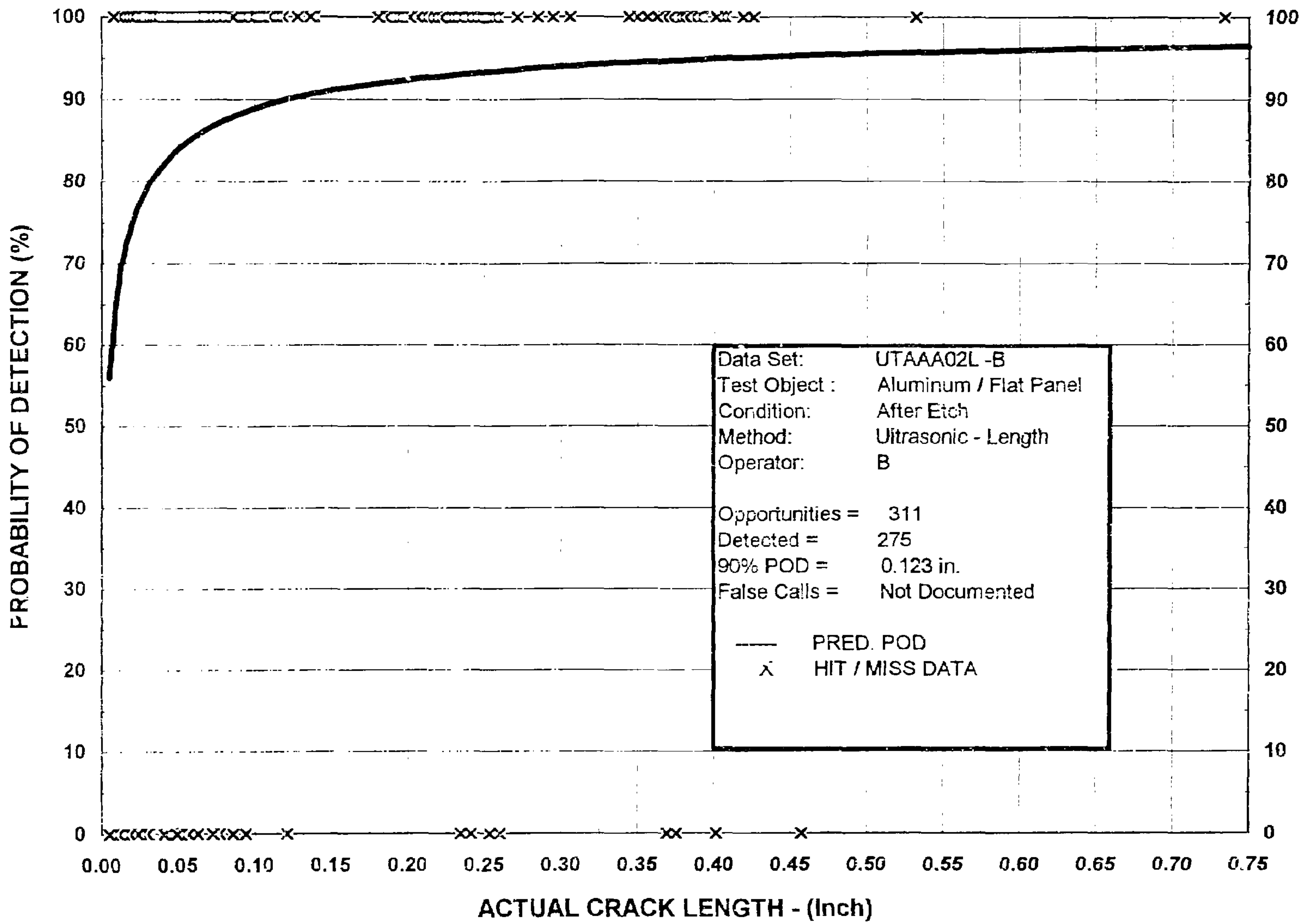
UT - 01 (1) CRACK LENGTH
6/95

UTAAA01L-C
Aluminum - Flat Plate



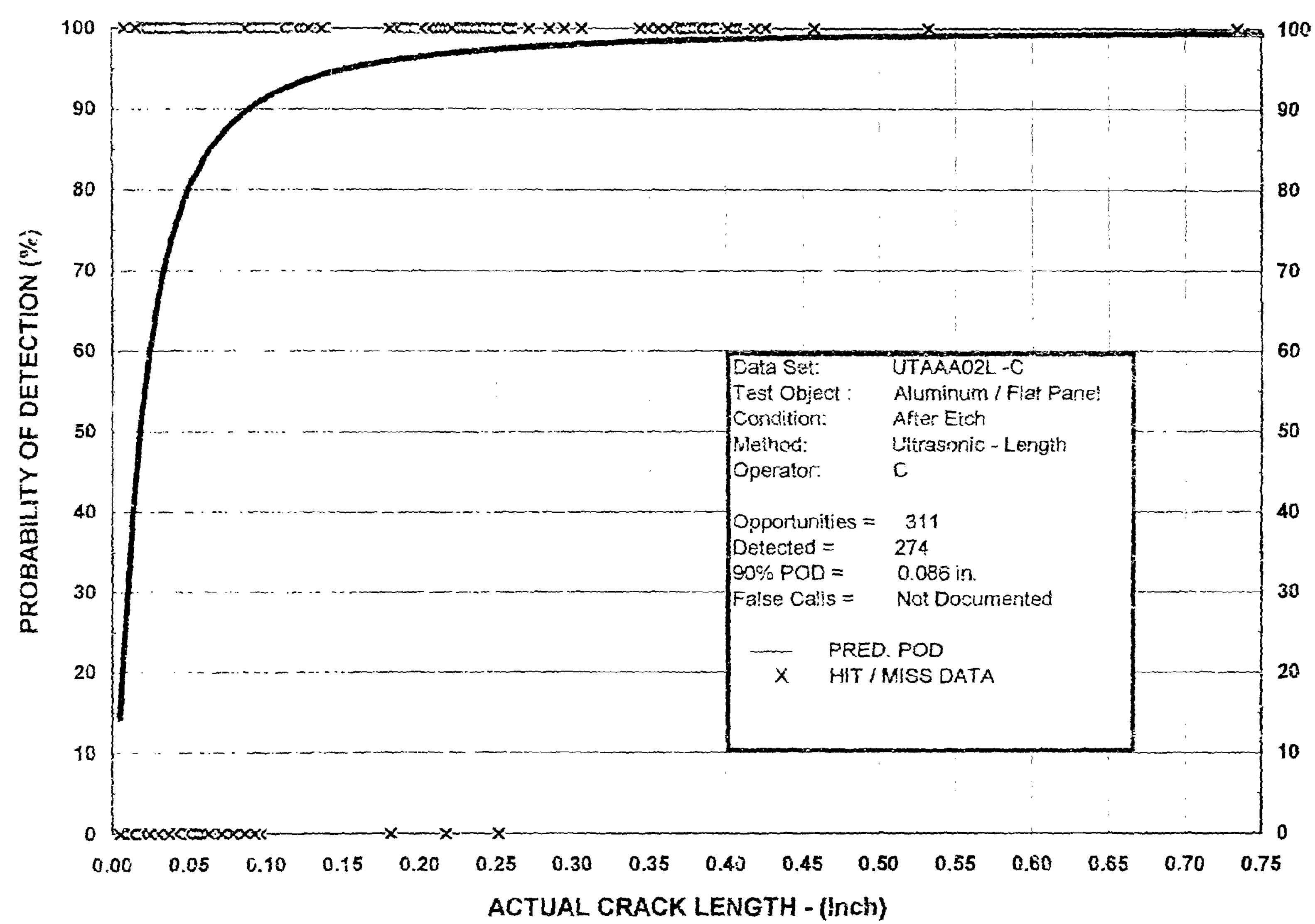
UT - 01 (1) CRACK LENGTH
6/95

UTAAA02L-A
Aluminum - Flat Plate



UT - 01 (1) CRACK LENGTH
6/95

UTAAA02L-B
Aluminum - Flat Plate

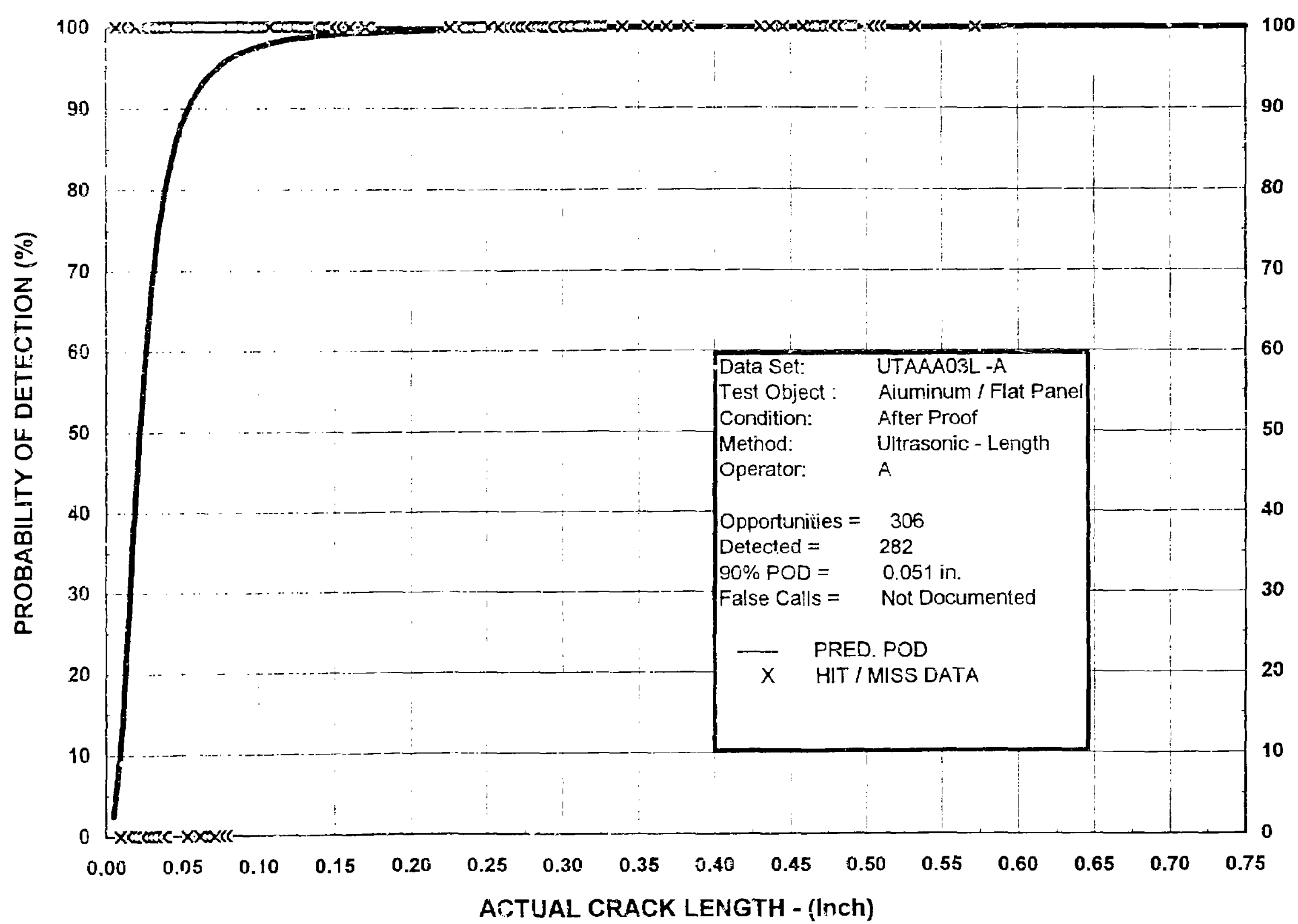


UT - 01 (1) CRACK LENGTH

6/95

UTAAA02L-C

Aluminum - Flat Plate

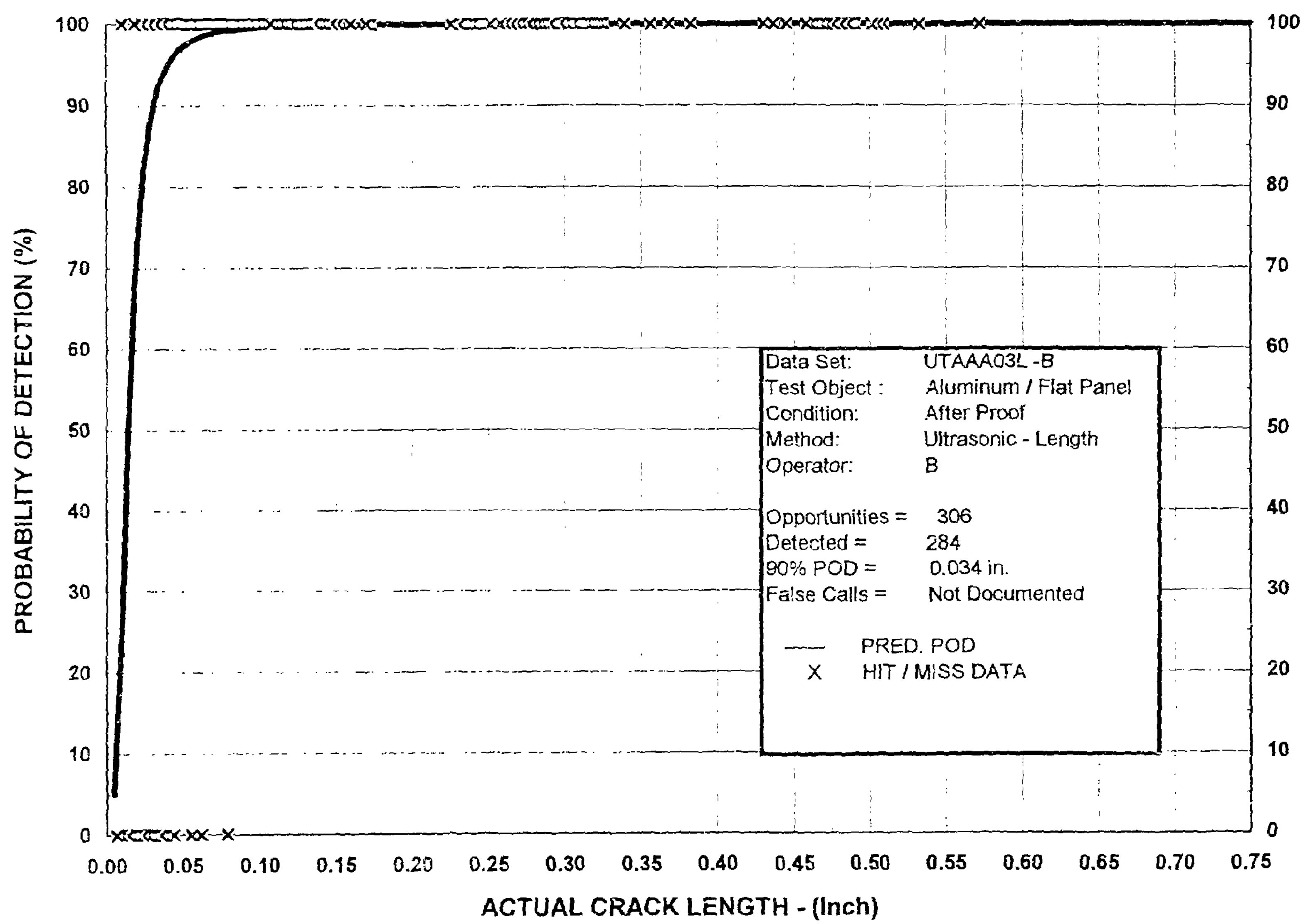


UT - 01 (1) CRACK LENGTH

6/95

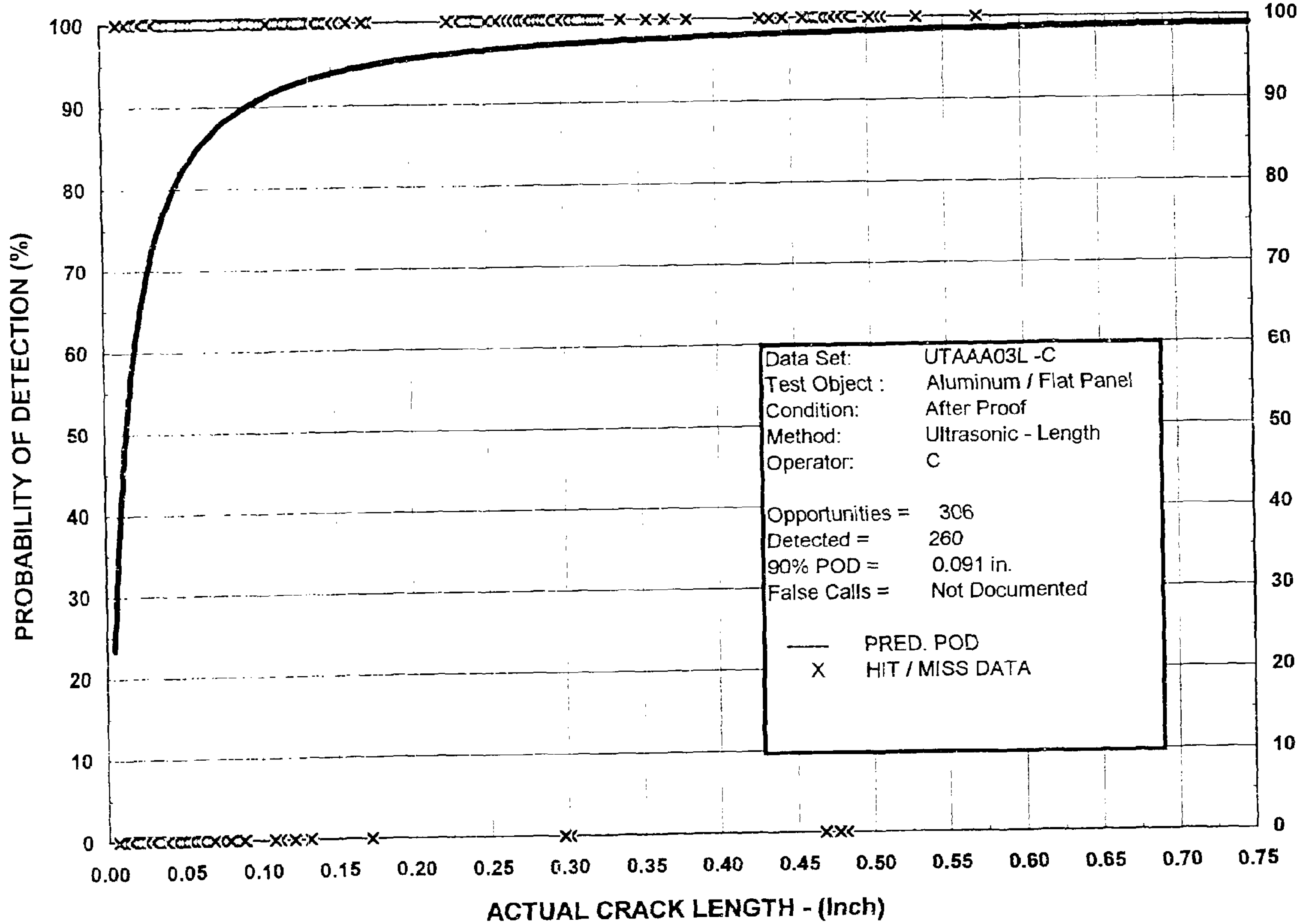
UTAAA03L-A

Aluminum - Flat Plate



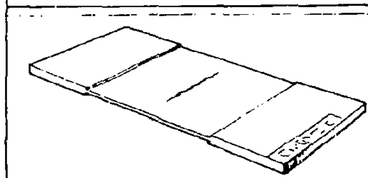
UT - 01 (1) CRACK LENGTH
6/95

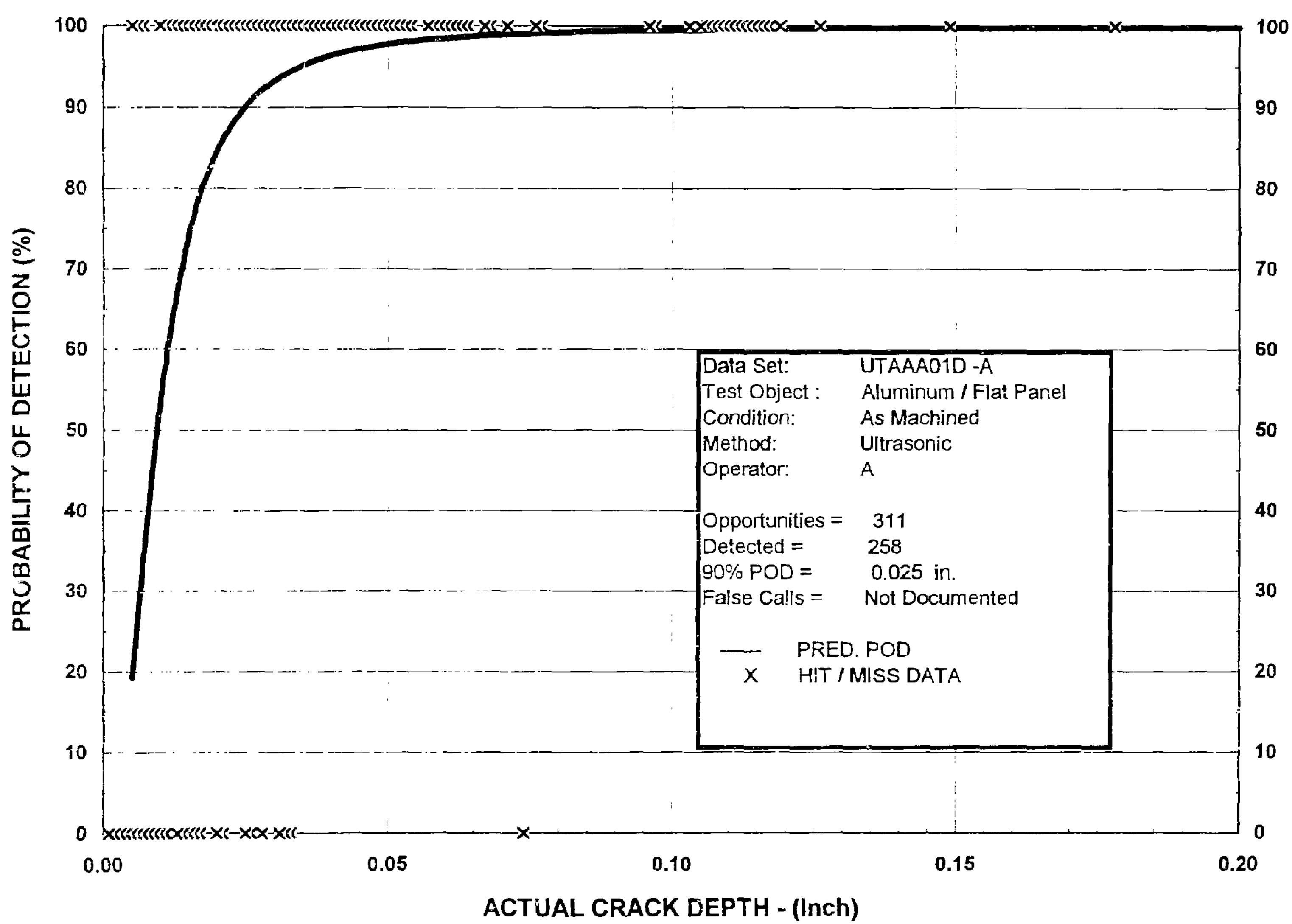
UTAAA03L-B
Aluminum - Flat Plate



UT - 01 (1) CRACK LENGTH
6/95

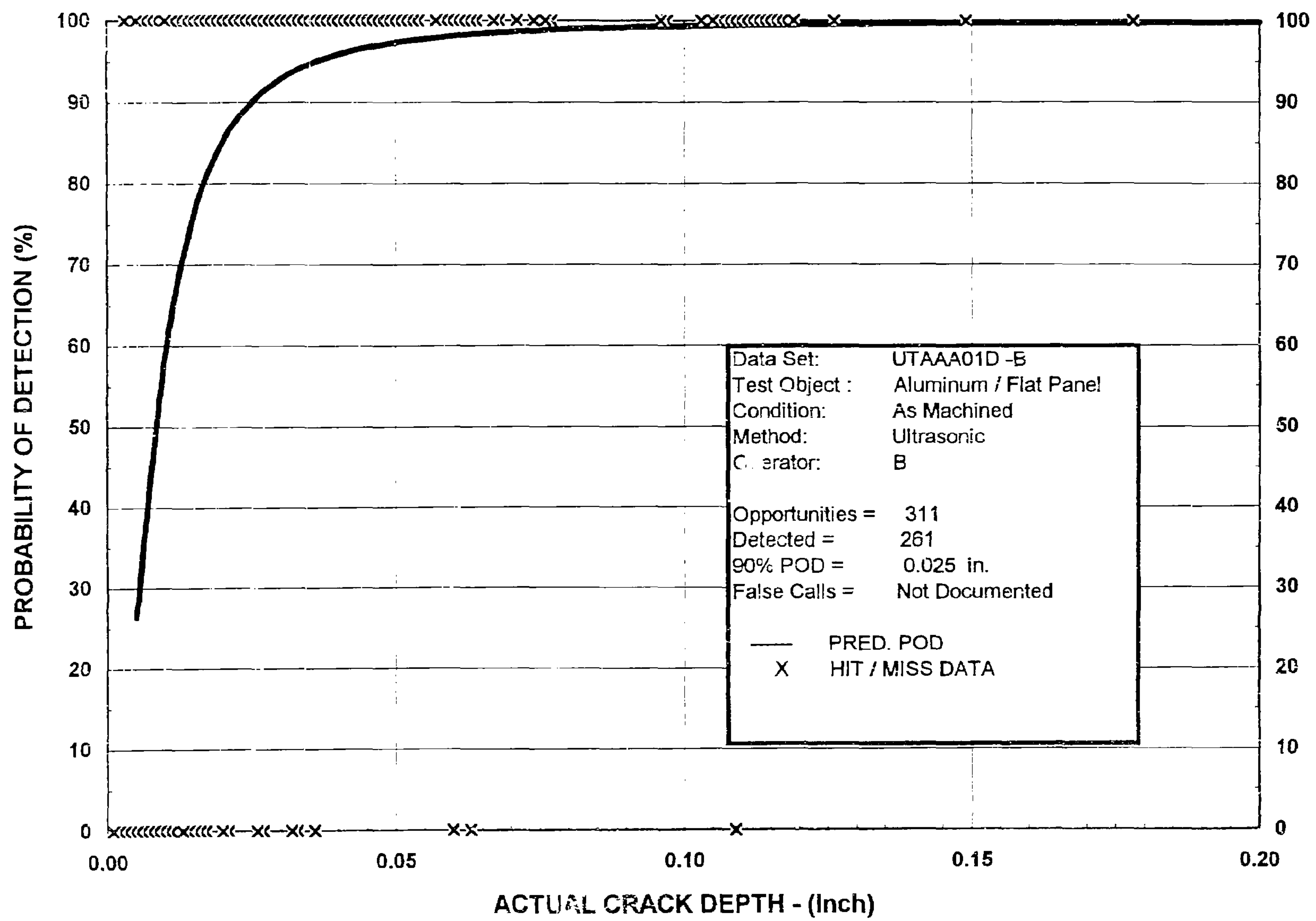
UTAAA03L-C
Aluminum - Flat Plate

UT - 01 (1) CRACK DEPTH	DATA SET DESCRIPTION			
METHOD:	Ultrasonic Surface Wave			
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides			
NDE PROCEDURE:	Ultrasonic Surface Wave - Immersion at 10MHz			
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension			
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)			
ARTIFACT VERIFICATION:	[illegible]structive analysis and measurement			
MATERIAL:	2219 Aluminum T-87			
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal			
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,"After Proof"			
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices			
APPLICATION:	Immersion - C-scan recording			
DATA SET IDENTIFIER:	UTAAA01D-A,B,C; UTAAA02D-A,B,C; UTAAA03D-A,B,C			
TYPE OF DATA:	Hit / Miss with estimated crack lengths			
TEST OPPORTUNITIES:	311 / 306 Cracks (5 cracks lost in proof test)			
DETECTED:	UTAAA01D-A= 258, B= 261, C= 254; 02D-A= 252, B= 275, C= 274; 03D-A= 282, B= 284, C= 260			
FALSE CALLS:	Not reported			
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **<u>The Detection of Fatigue Cracks by Nondestructive Testing Methods</u>**. February 1974.			
DATE:	November 1971 - June 1973			
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center			
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado			
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).			
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels			
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.			
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.			
	90% POD Depth -	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
		A= 0.025 in.	A= 0.056 in.	A= 0.014 in.
		B= 0.025 in.	B= 0.016 in.	B= 0.015 in.
		C= 0.024 in.	C= 0.025 in.	C= 0.031 in.



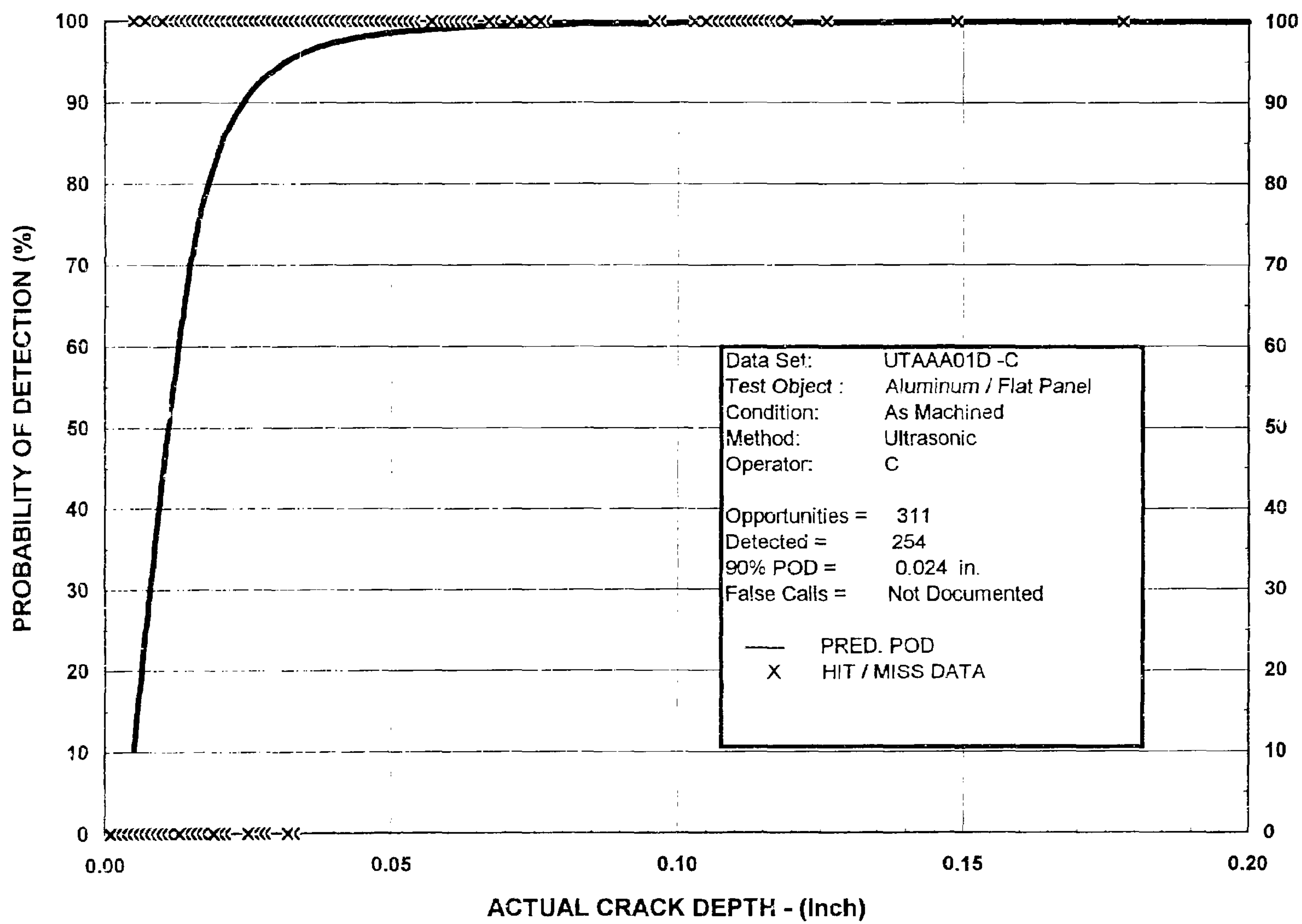
UT - 01 (1) CRACK DEPTH
6/95

UTAAA01D-A
Aluminum - Flat Plate



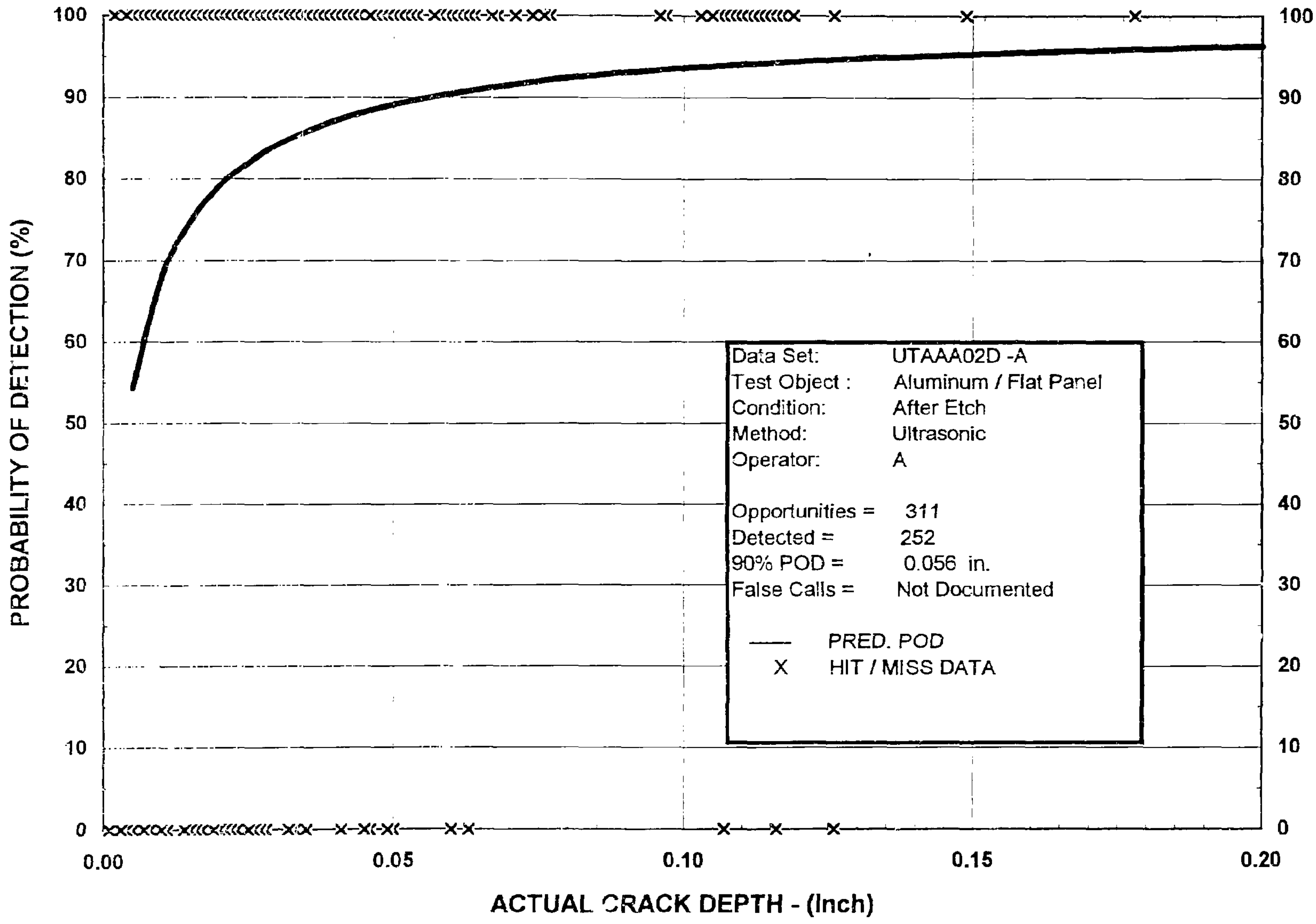
UT - 01 (1) CRACK DEPTH
6/95

UTAAA01D-B
Aluminum - Flat Plate



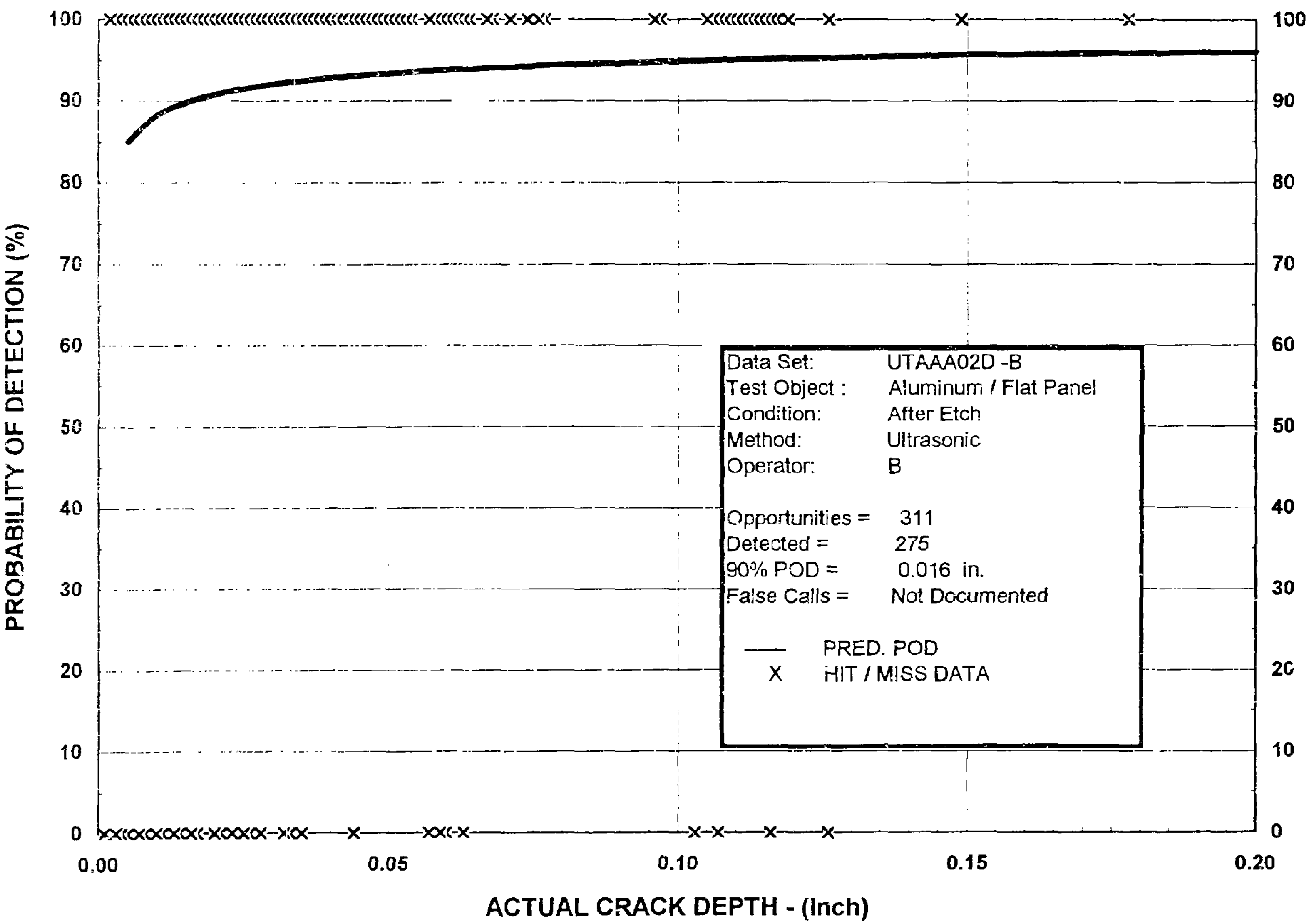
UT - 01 (1) CRACK DEPTH
6/95

UTAAA01D-C
Aluminum - Flat Plate



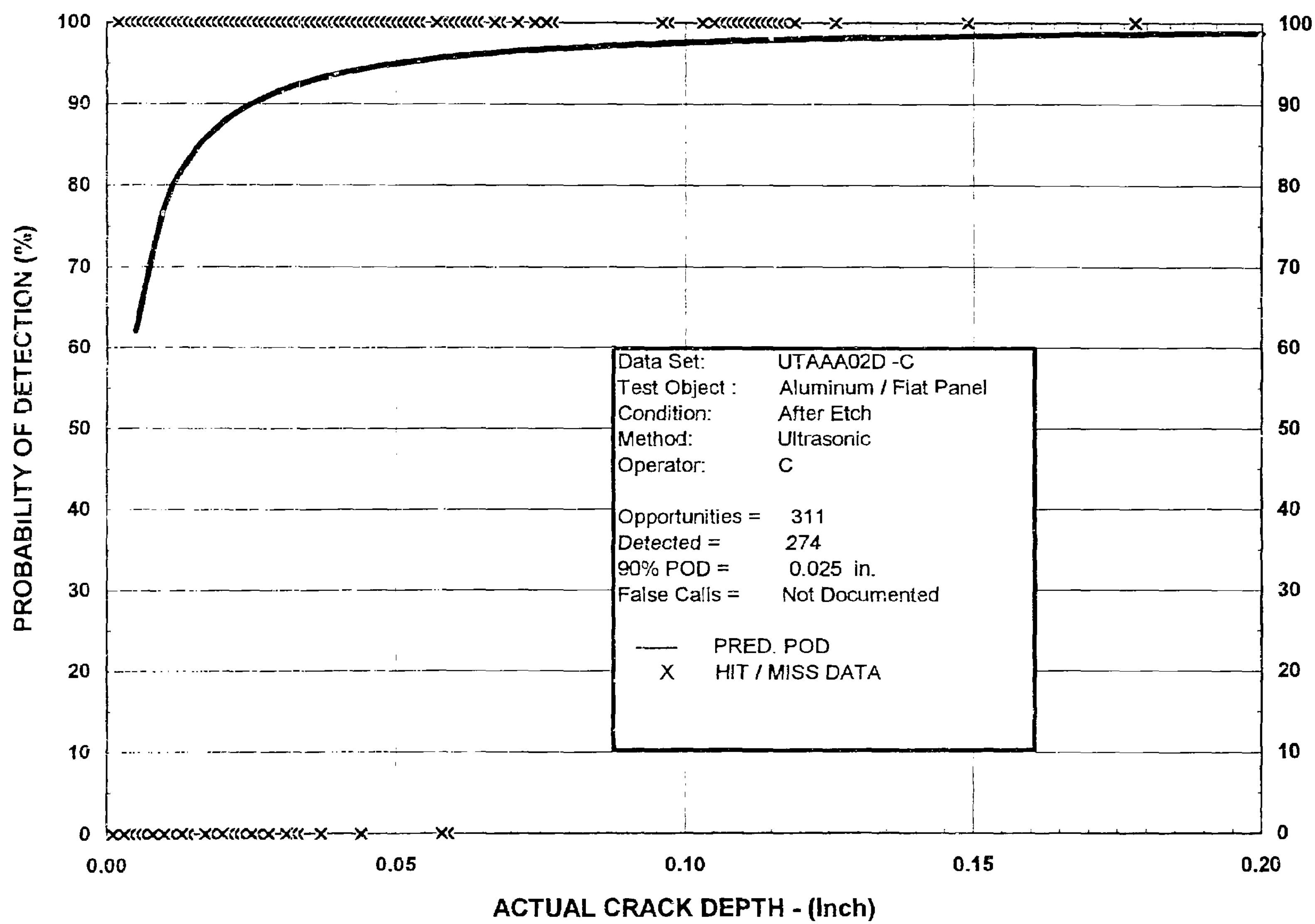
UT - 01 (1) CRACK DEPTH
6/95

UTAAA02D-A
Aluminum - Flat Plate



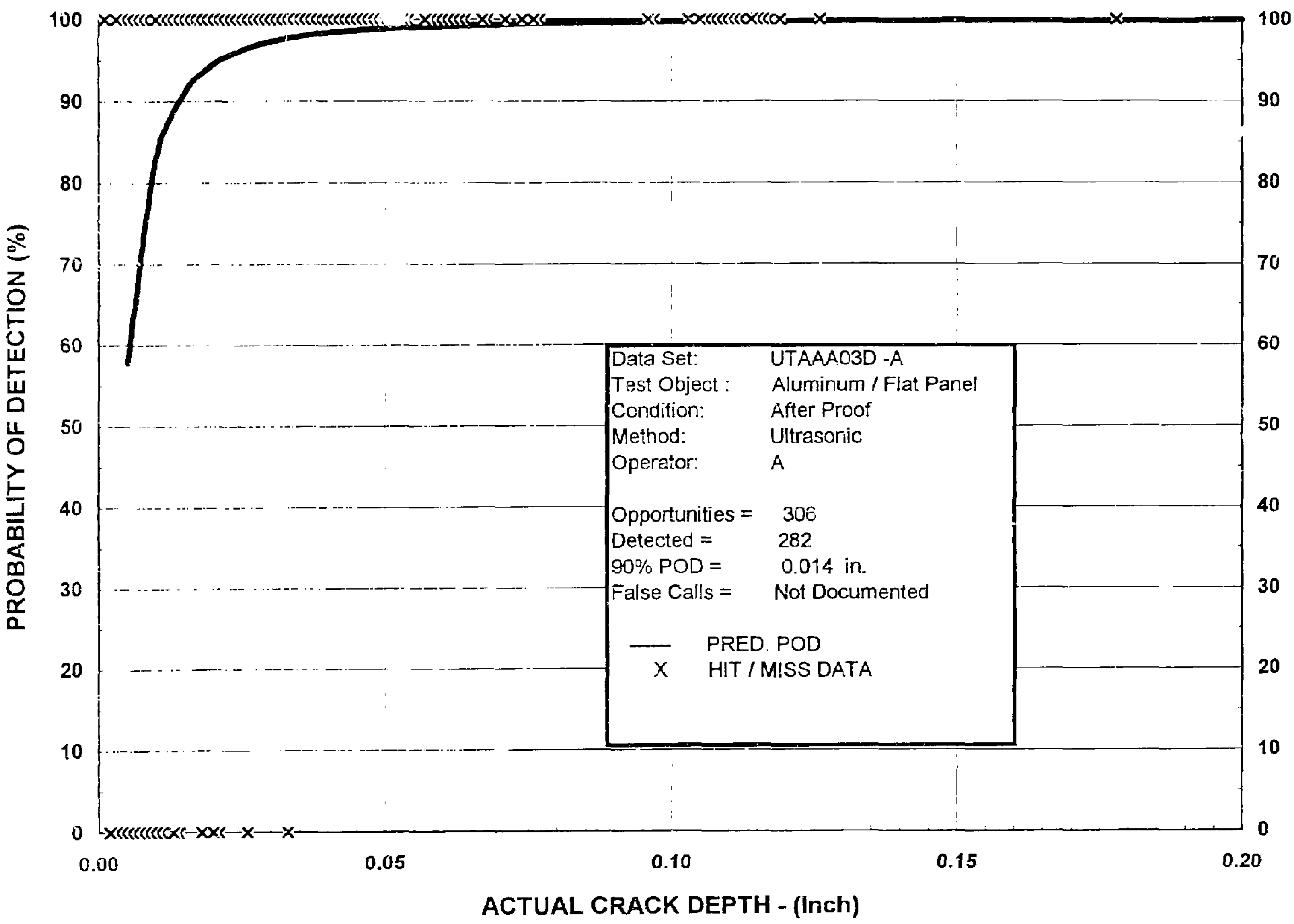
UT - 01 (1) CRACK DEPTH
6/95

UTAAA02D-B
Aluminum - Flat Plate



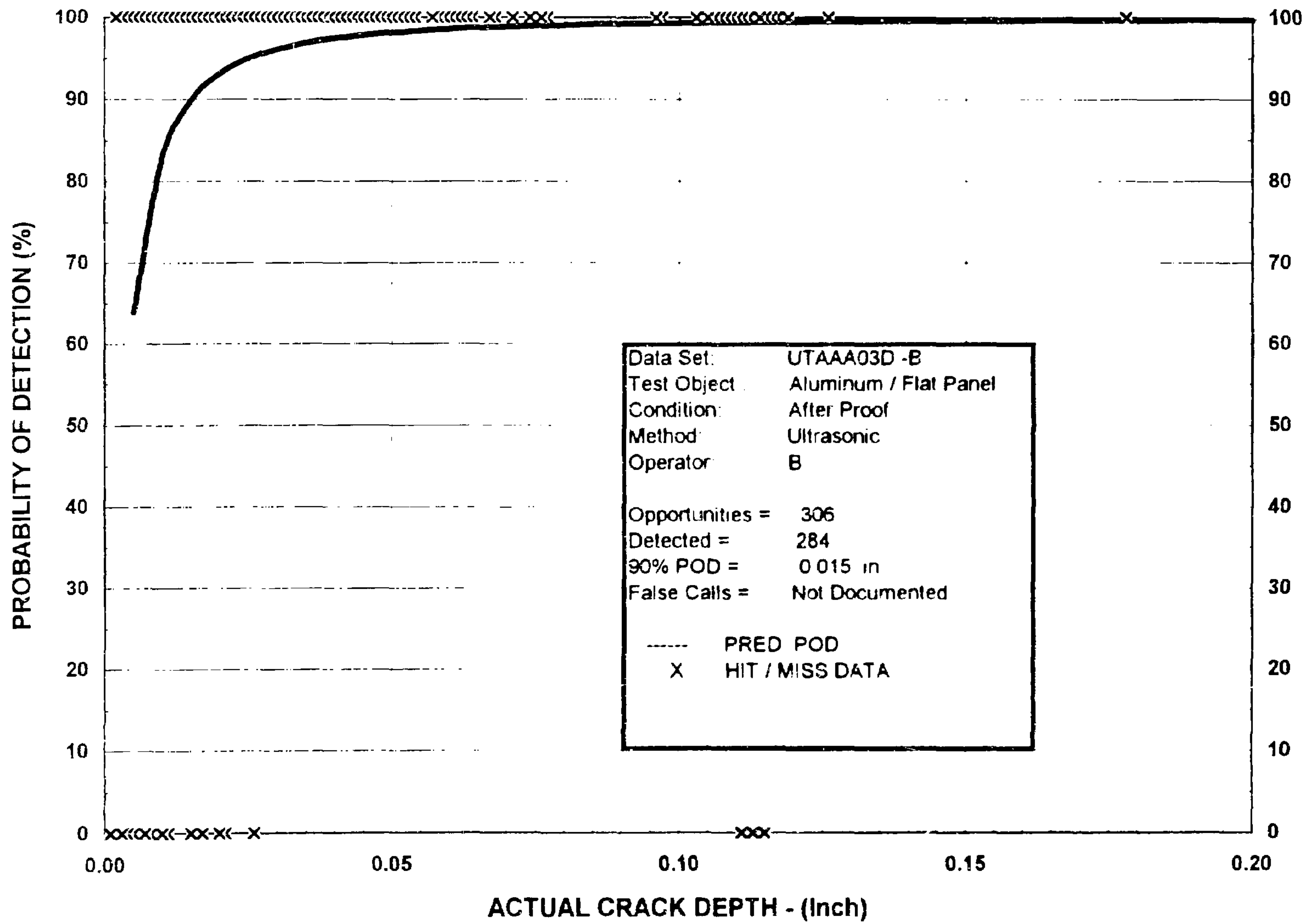
UT - 01 (1) CRACK DEPTH
6/95

UTAAA02D-C
Aluminum - Flat Plate



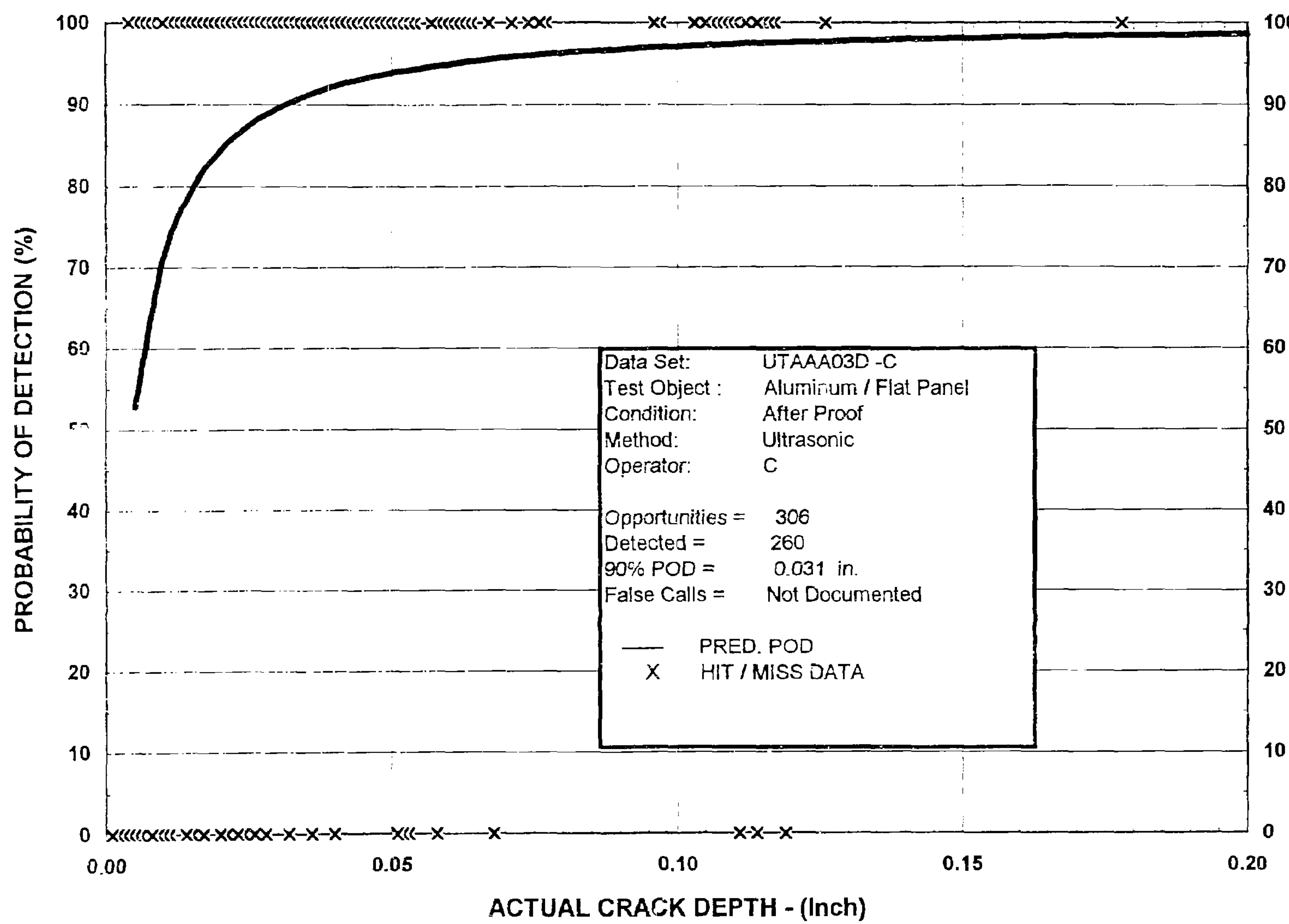
UT - 01 (1) CRACK DEPTH
6/95

UTAAA03D-A
Aluminum - Flat Plate



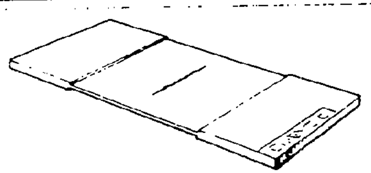
UT - 01 (1) CRACK DEPTH
6/95

UTAAA03D-B
Aluminum - Flat Plate



UT - 01 (1) CRACK DEPTH
6/95

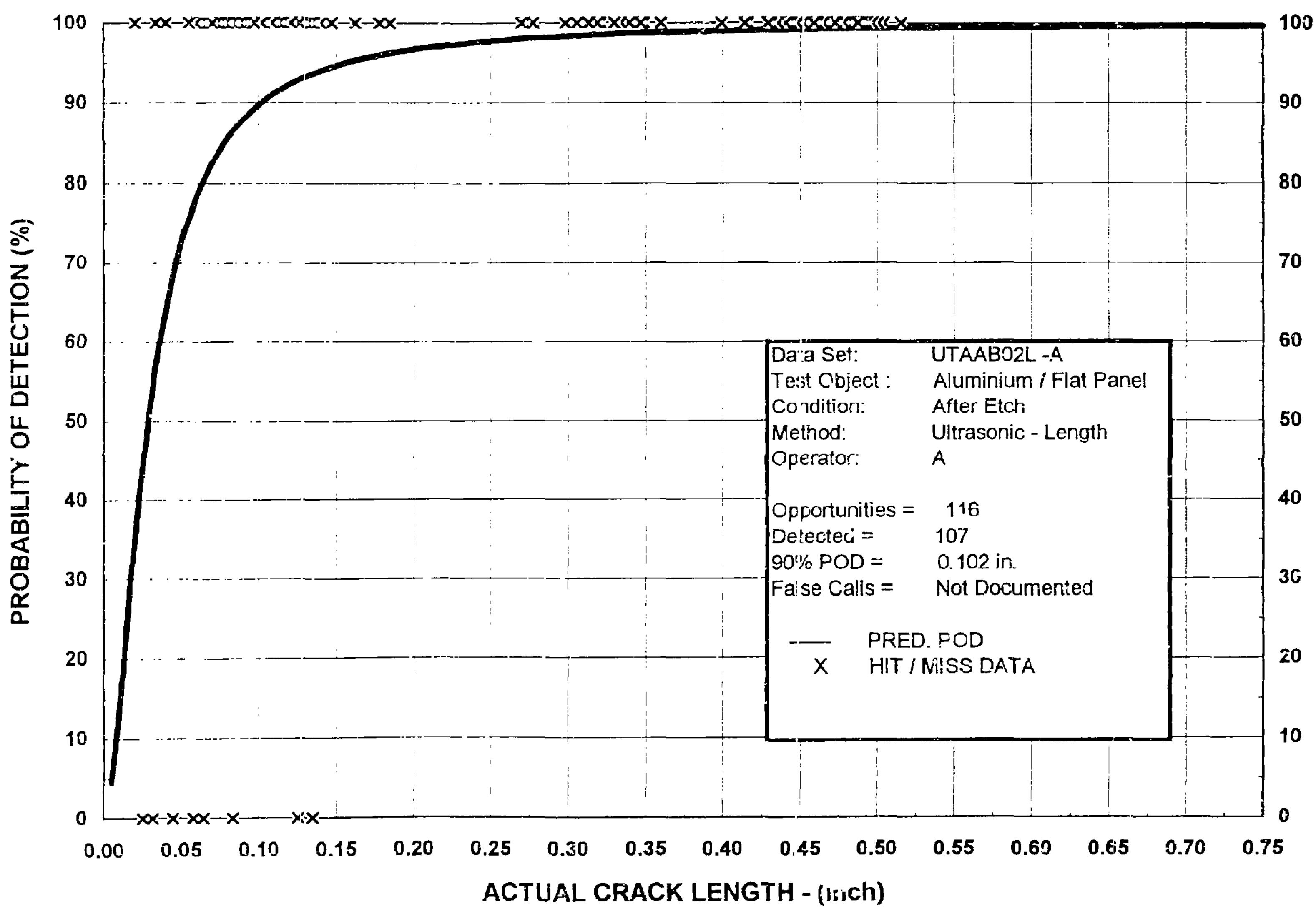
UTAAA03D-C
Aluminum - Flat Plate

UT - 02 (1)	DATA SET DISCRIPTION	
METHOD:	Ultrasonic Inspection	
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides (General Dynamics Panels)	
NDE PROCEDURE:	Ultrasonic Surface Wave - Immersion at 10 MHz	
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension	
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)	
ARTIFACT VERIFICATION:	Destructive analysis and measurement	
MATERIAL:	2219 Aluminum T-87	
TEST OBJECT THICKNESS:	0.085 and 0.225 inch nominal	
TEST OBJECT CONDITION:	"After Etch"	
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices	
APPLICATION:	Manual Inspection / Manual Recording	
DATA SET IDENTIFIER:	UTAAB02L-A,B,C; UTAAB02D-A,B,C	
TYPE OF DATA:	Hit / Miss with estimated crack lengths	
TEST OPPORTUNITIES:	116 Cracks	
DETECTED:	UTAAB02L-A= 107 , B= 106, C= 109; UTAAB02D-A=107, B= 106, C= 109	
FALSE CALLS:	Not reported	
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.	
DATE:	November 1971 - June 1973	
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center	
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado	
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).	
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels	
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.	
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**	
	90% POD "AFTER ETCH - CRACK LENGTH"	"AFTER ETCH - CRACK DEPTH"
	A= 0.102 in.	A= 0.025 in
	B= 0.109 in.	B= 0.026 in
	C= 0.084 in.	C= 0.020in.

UT - 02 (1) GENERAL DYNAMICS

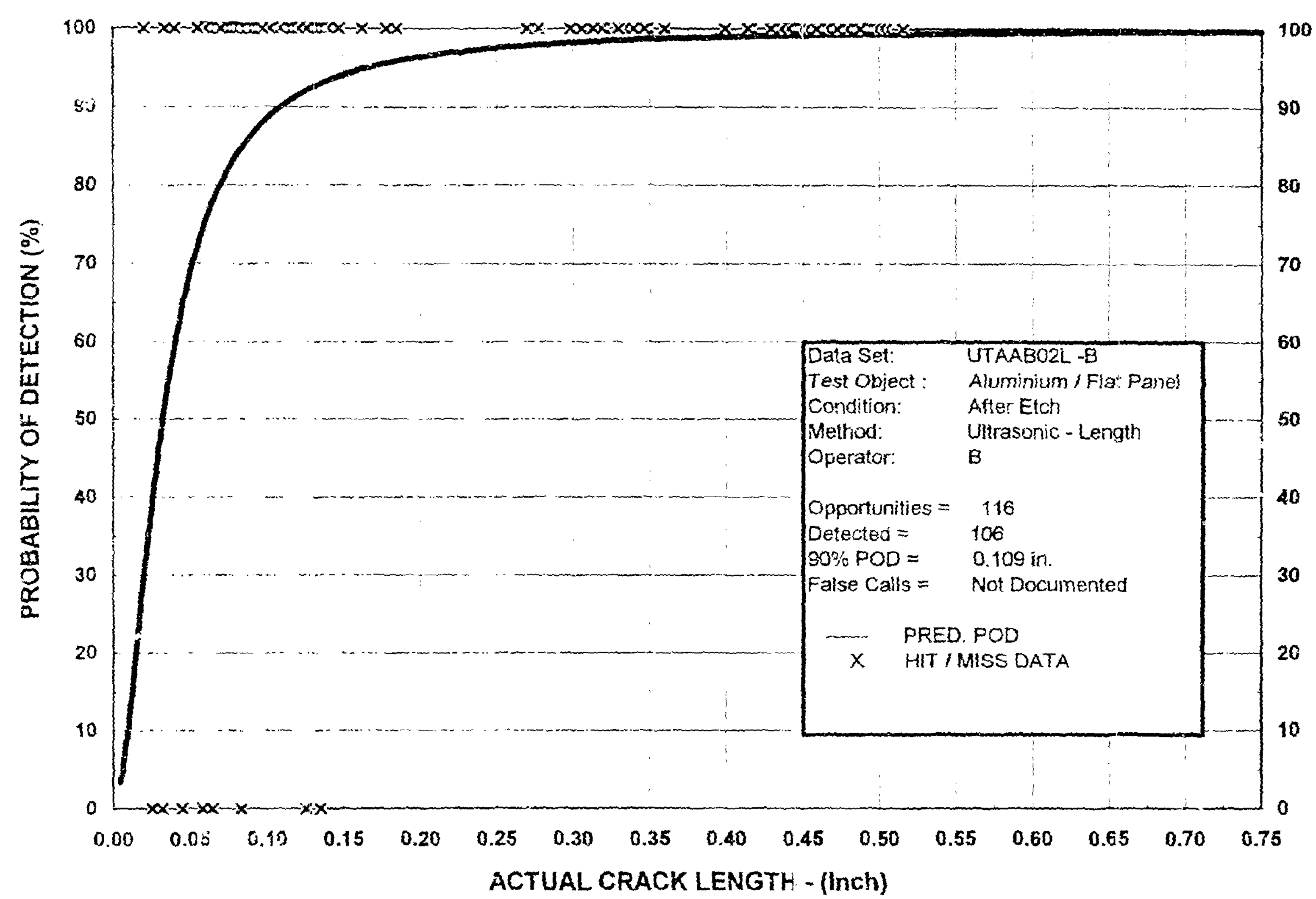
6/95

ULTRASONIC INSPECTION
ALUMINUM - FLAT PANELS



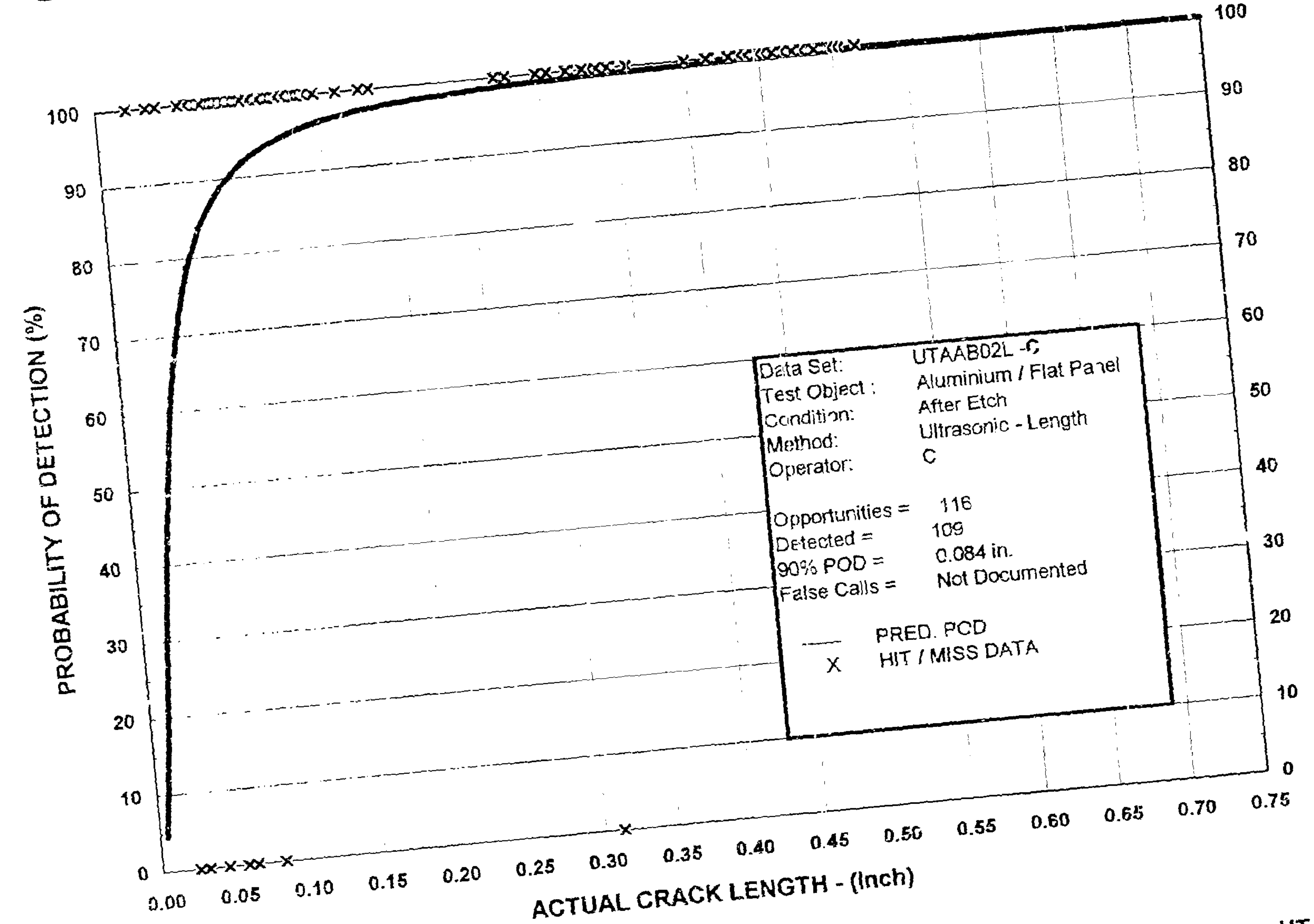
UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95

UTAAB02L-A
AFTER ETCH - OPERATOR A



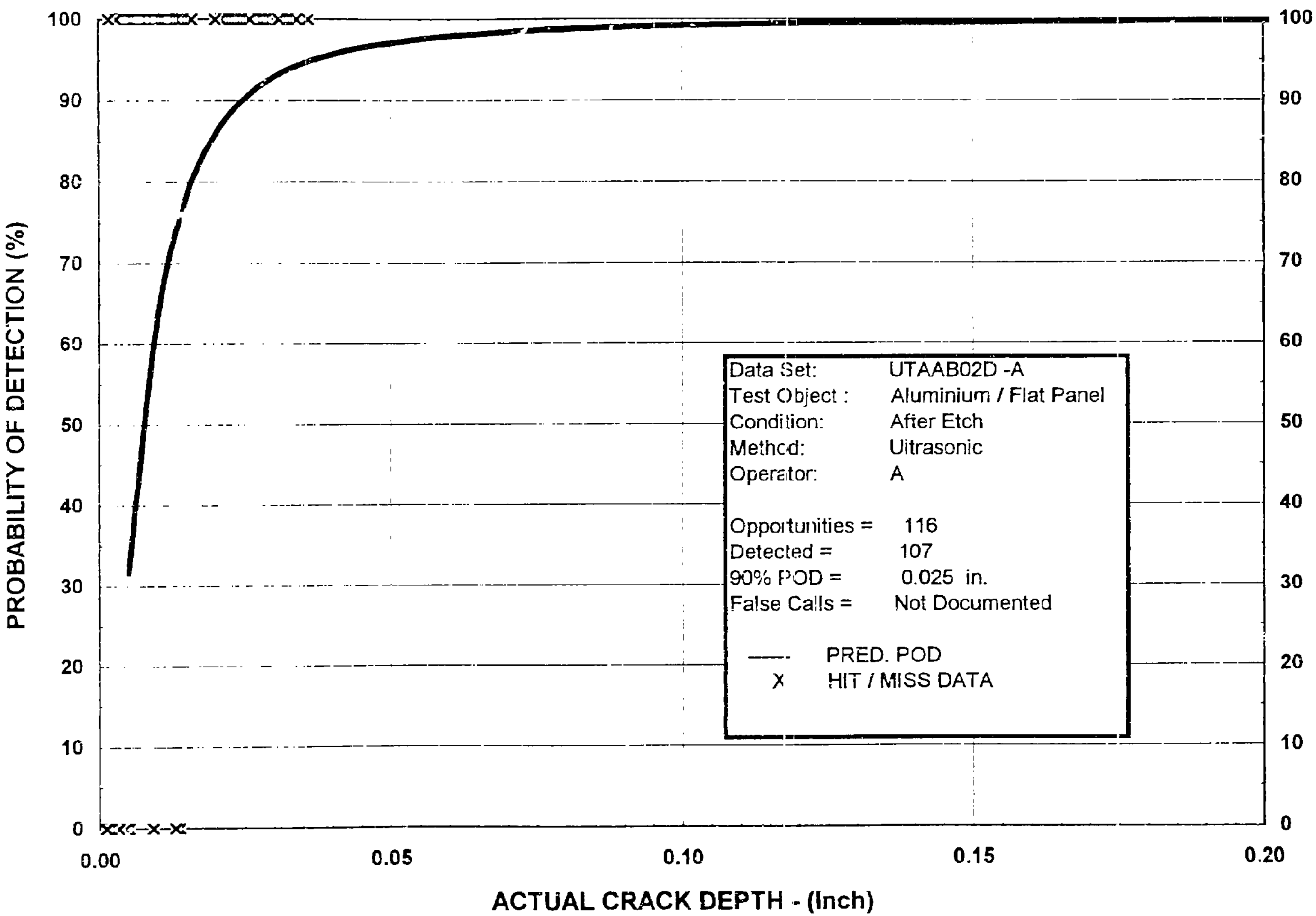
UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95

UTAAB02L-B
AFTER ETCH - OPERATOR B



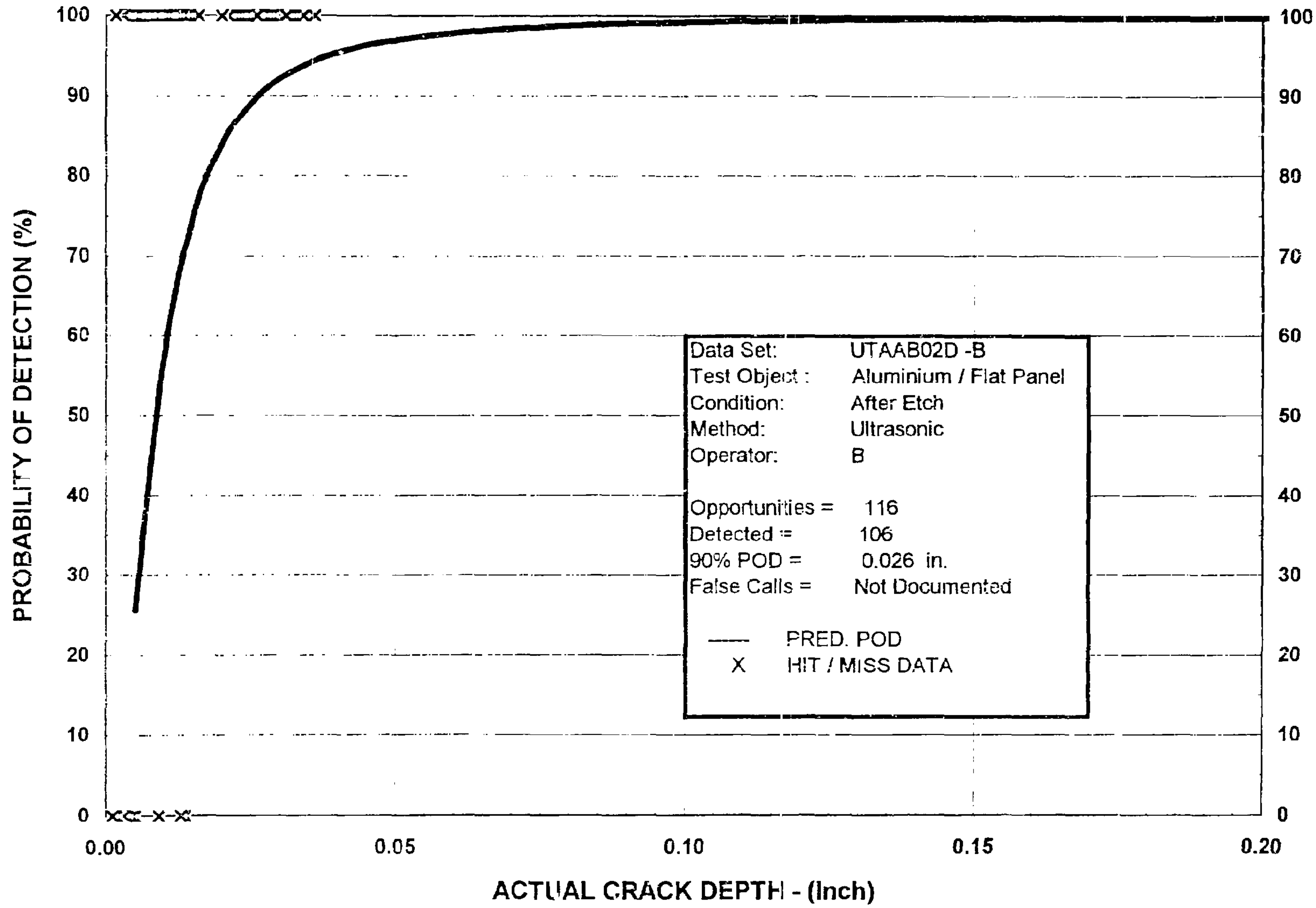
UTAAB02L-C
AFTER ETCH - OPERATOR C

UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95



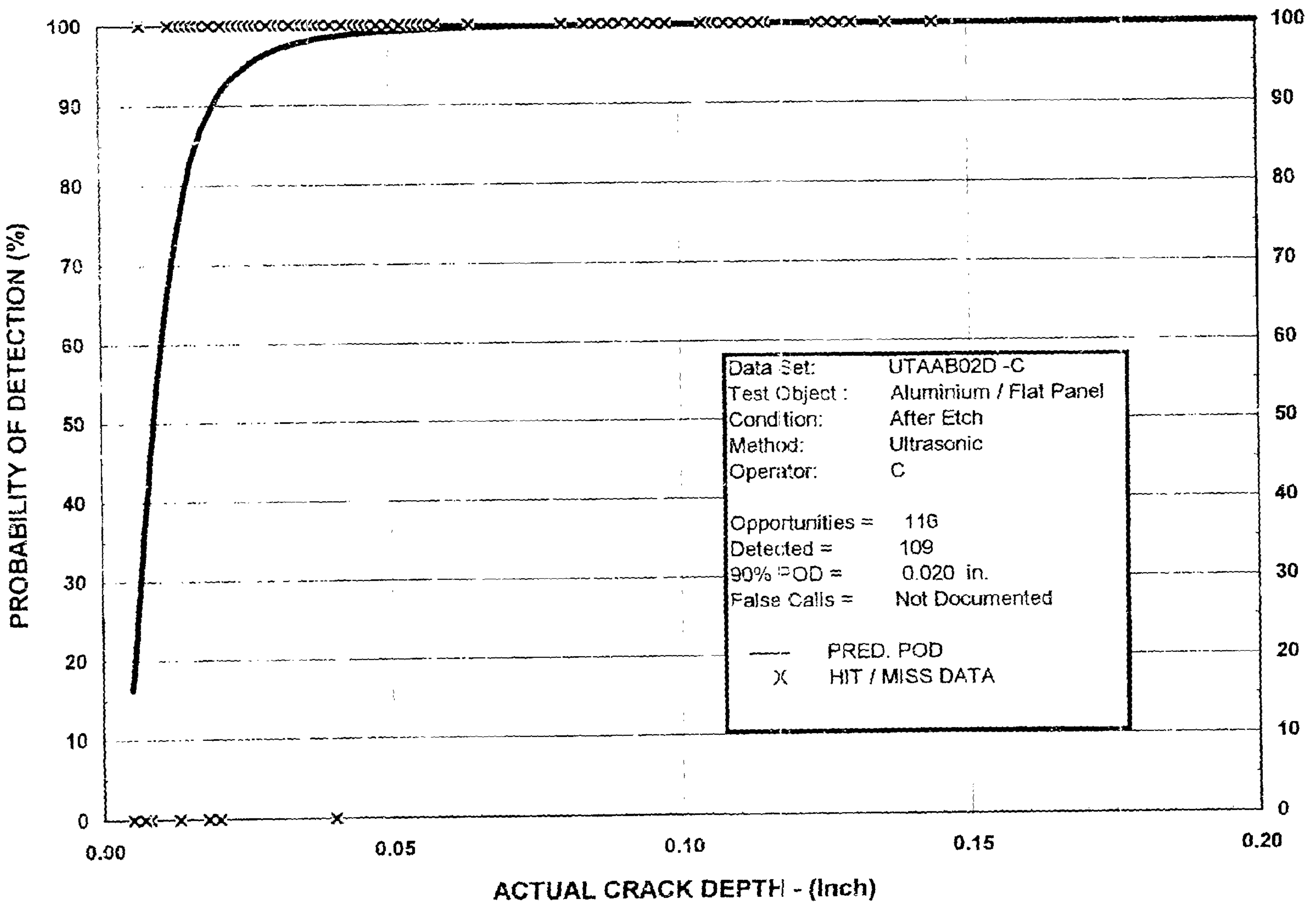
UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95

UTAAB02D-A
AFTER ETCH - OPERATOR A



UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95

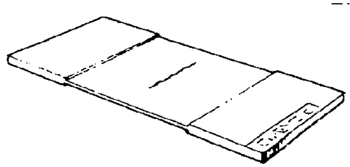
UTAAB02D-B
AFTER ETCH - OPERATOR B



UT - 02 (1) ULTRASONIC
GENERAL DYNAMICS ALUMINUM PANELS
6/95

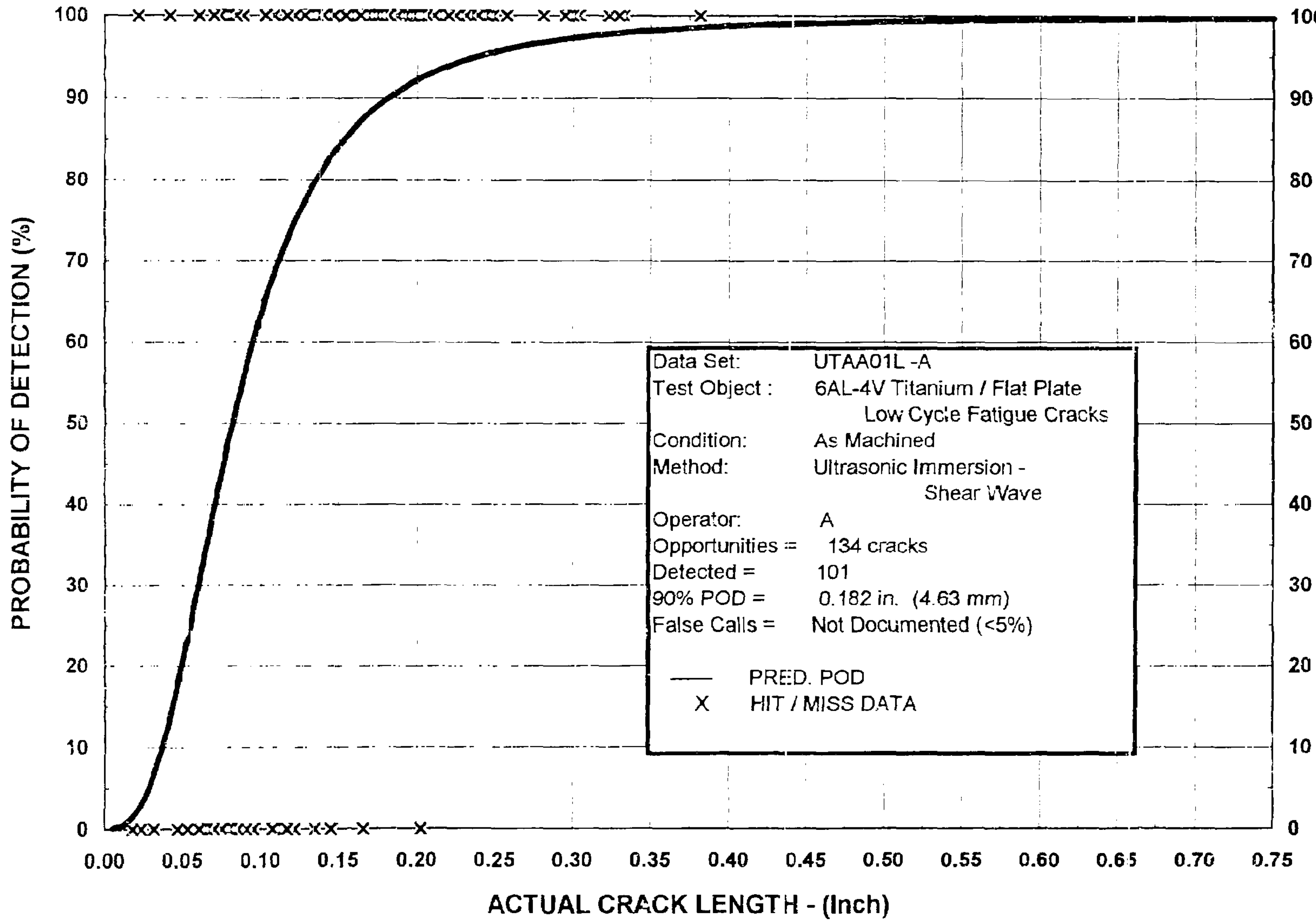
UTAAB02D-C
AFTER ETCH - OPERATOR C

UT 03 (2)	DATA SET DISCRIPTION
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Ultrasonic Surface Wave - Immersion at 5 MHz
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Titanium plate - 6Al4V
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	"As Machined"; "After Etch"; "After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Immersion C-scan Recording / Manual read-out
DATA SET IDENTIFIER:	UTAA01L - A ,B,C; UTAA03L - A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	134/5Cracks (161 original - Some cracks lost in machining)
DETECTED:	UTAA01L - A= 101, B= 98, C= 108; UTTAA03L - A= 105, B= 115, C=116
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



90% POD	"AS MACHINED"	"AFTER PROOF"
	A= 0.182 in. (4.63 mm)	A= 0.265 in (6.73 mm)
	B= 0.231 in. (5.86 mm)	B= 0.111 in. (2.82 mm)
	C= 0.139 in. (3.54 mm)	C= 0.133 in. (3.38 mm)

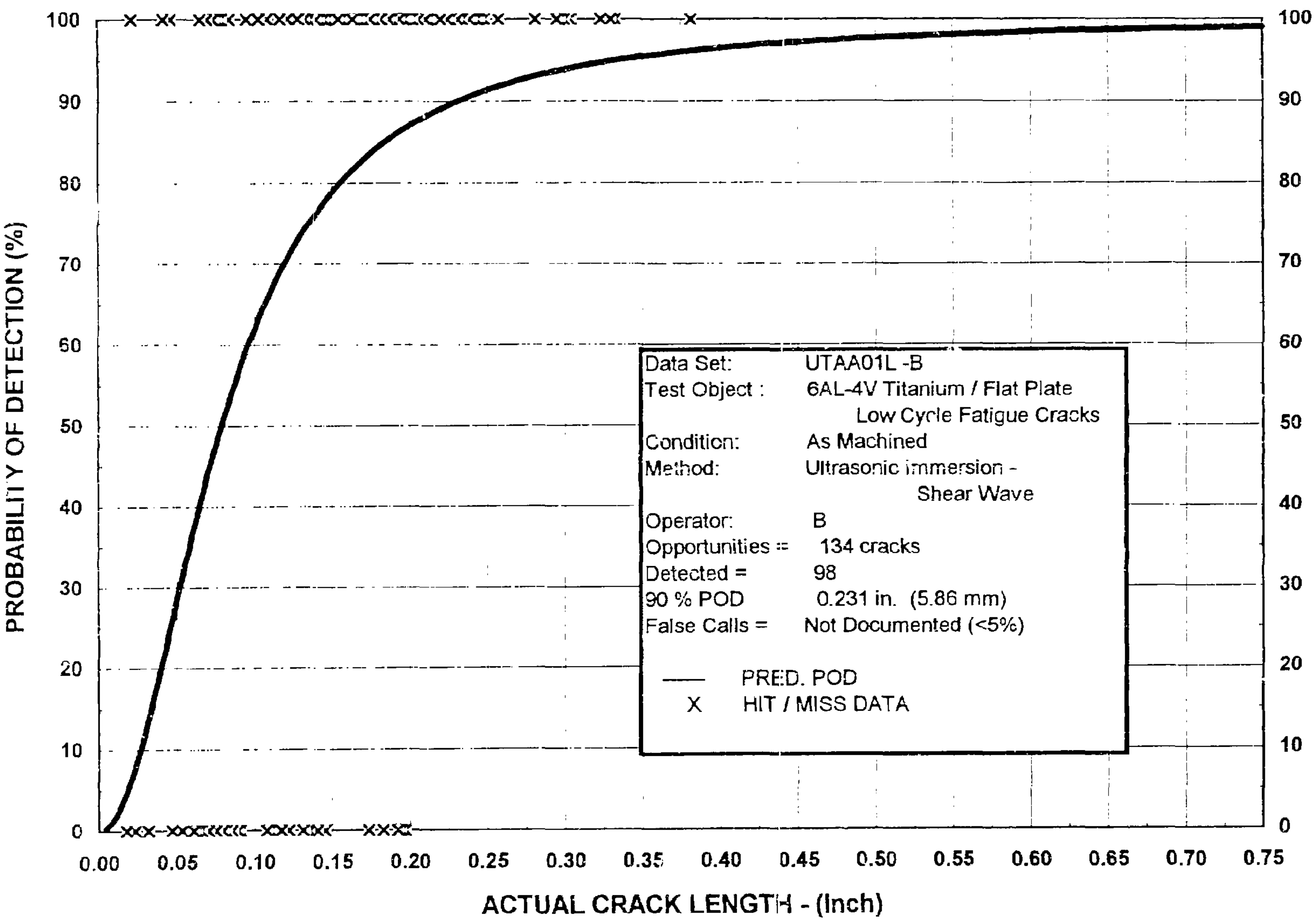
ULTRASONIC SURFACE WAVE TITANIUM PANELS



UTAA01L-A
AS MACHINED - OPERATOR A

UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS

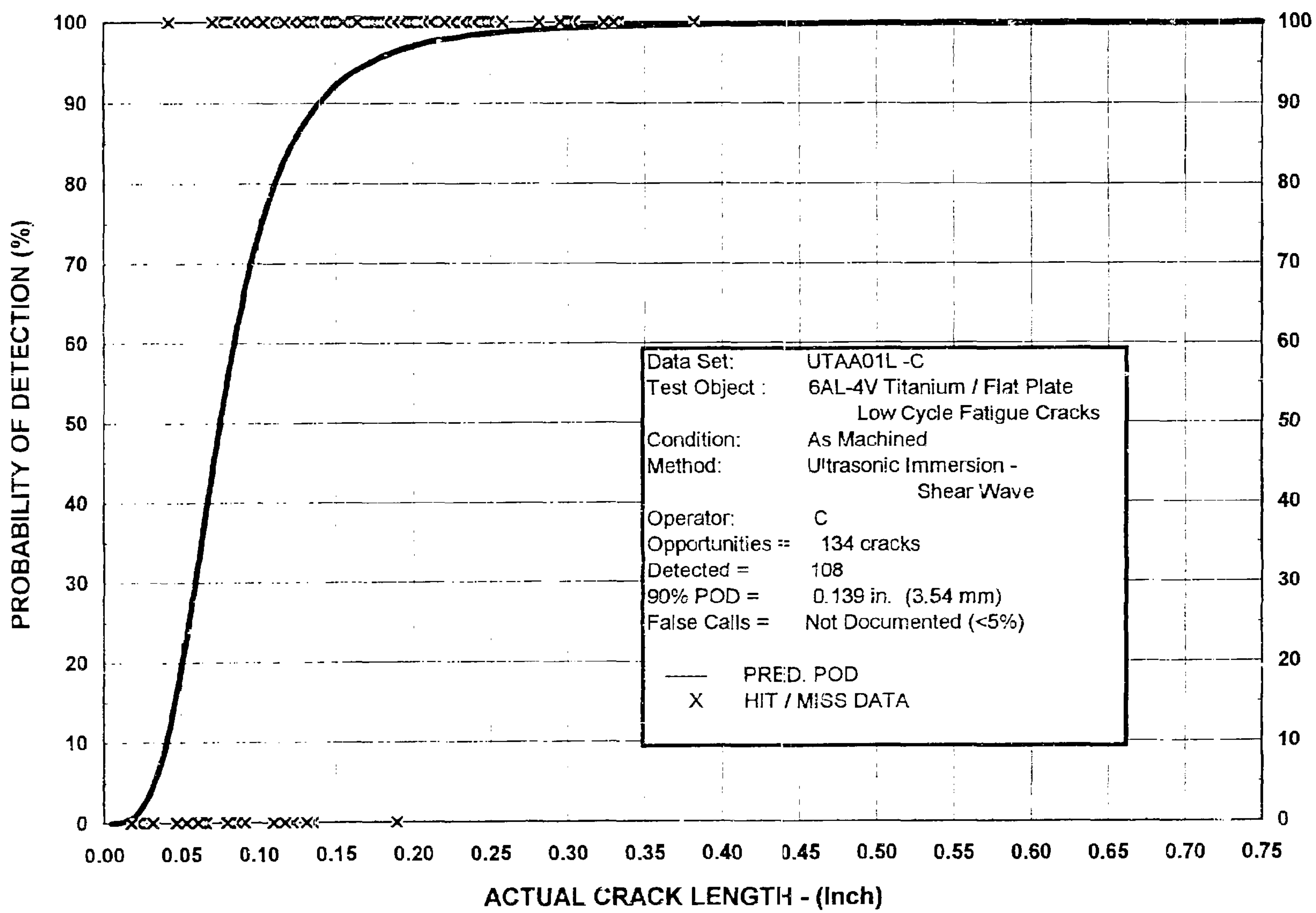
6/95



UTAA01L-B
AS MACHINED - OPERATOR B

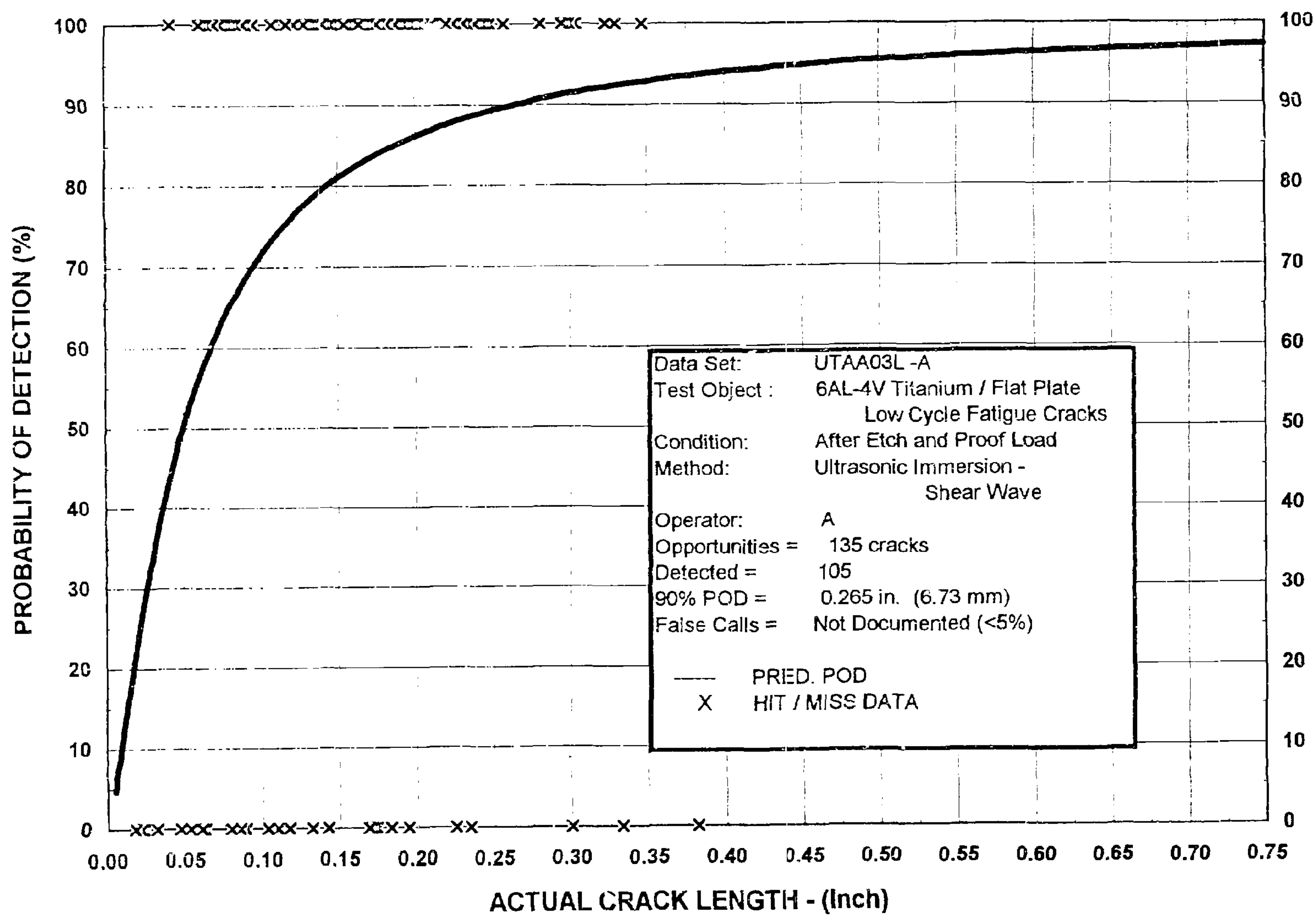
UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS

6/95



UTAA01L-C
AS MACHINED - OPERATOR C

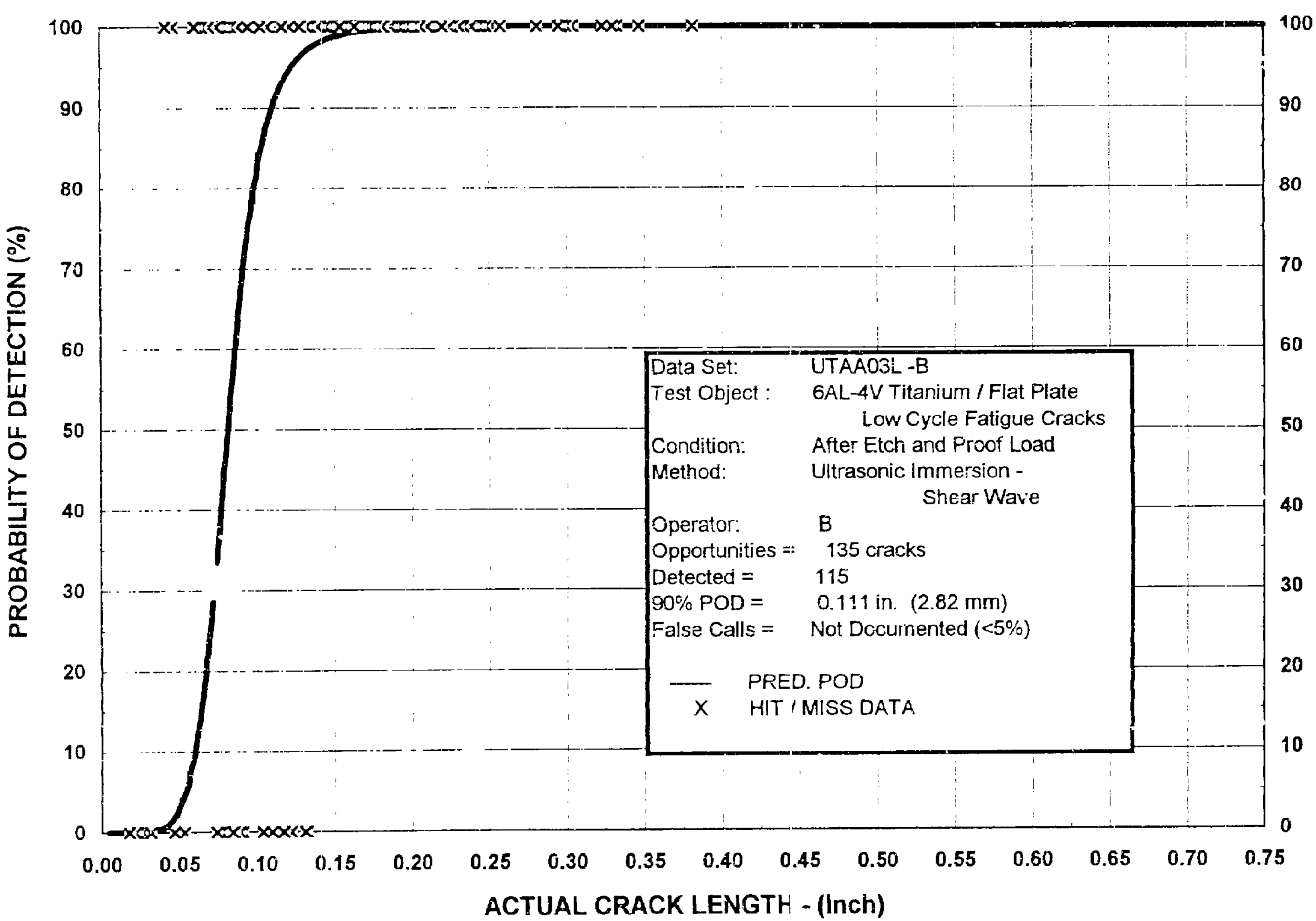
UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS
6/95



UTAA03L-A
AFTER ETCH AND PROOF - OPERATOR A

UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS

6/95

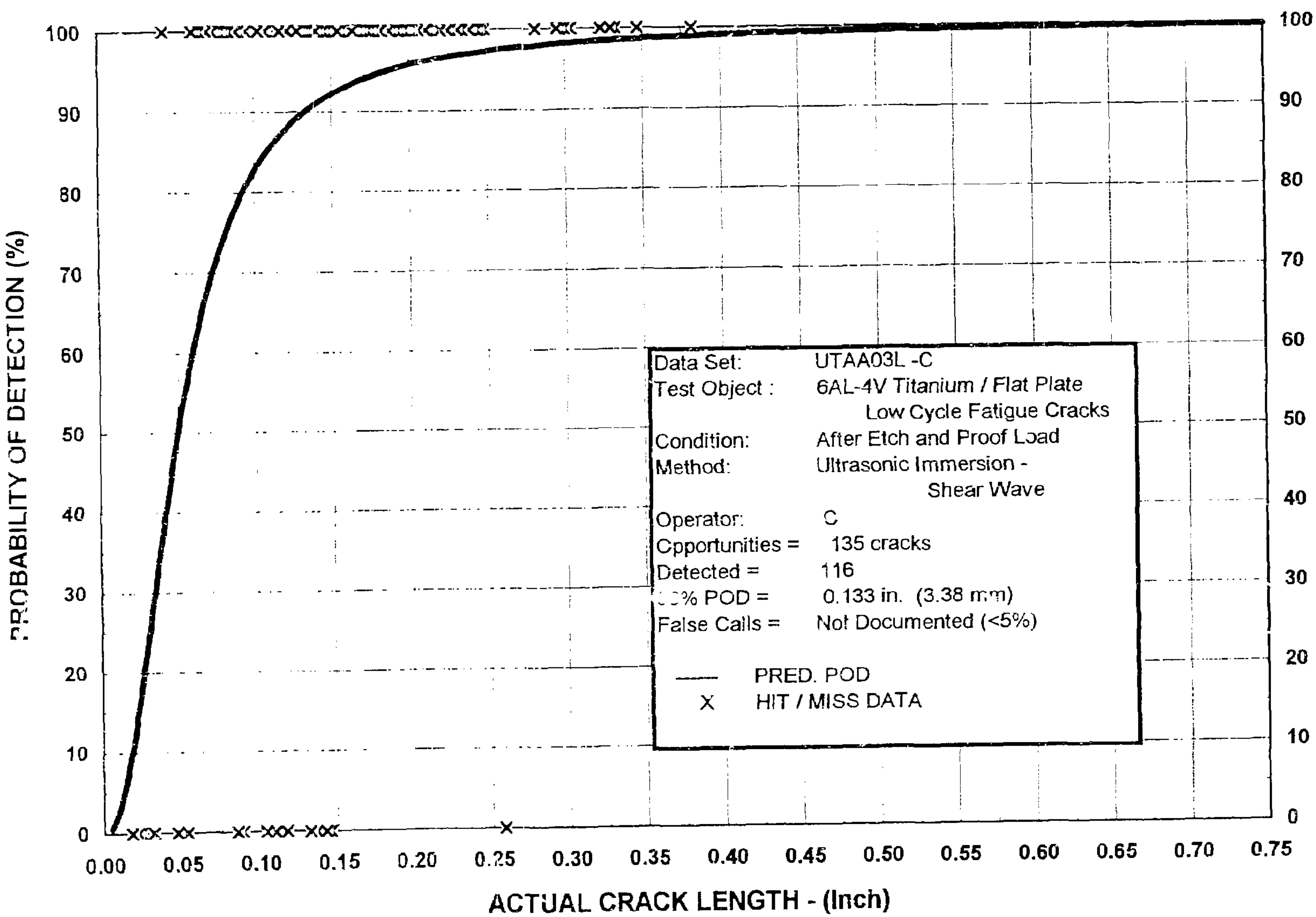


UTAA03L-B

AFTER ETCH AND PROOF - OPERATOR B

UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS

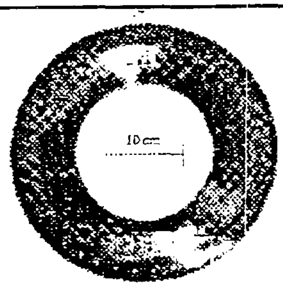
6/95

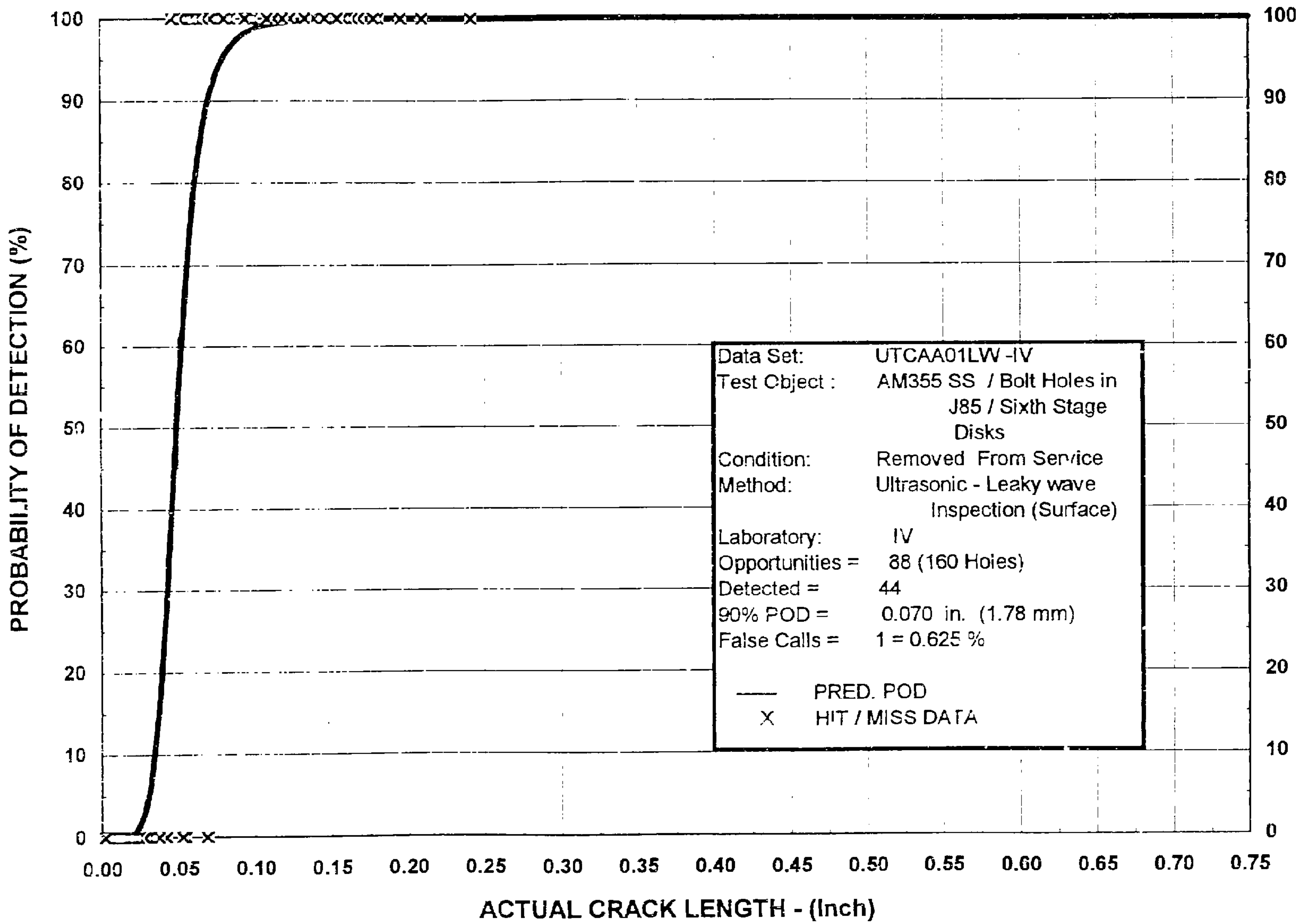


UTAA03L-C
AFTER ETCH AND PROOF - OPERATOR C

UT - 03 (2) ULTRASONIC INSPECTION OF TITANIUM PANELS

6/95

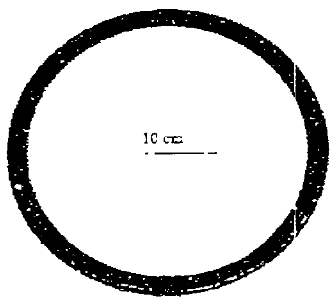
UT-04 (4)	DATA SET DISCRIPTION
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Bolt holes in J85 / Sixth stage compressor disks; 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Ultrasonic Inspection - Leaky Wave
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	*Condition as removed from service - original* surface rough polished
APPLICATION:	Immersion Inspection / Manual Read-out
DATA SET IDENTIFIERS:	UTCAA01LW -IV
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	IV: 160 holes/88 cracks
DETECTED:	ORG IV: 44
FALSE CALLS:	ORG IV: 1 = 0.625 %
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHVC0
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD ORG IV: 0.070 in. (1.78mm)



UT - 04 (4) ULTRASONIC INSPECTION OF GAS TURBINE ENGINE DISKS
06/95

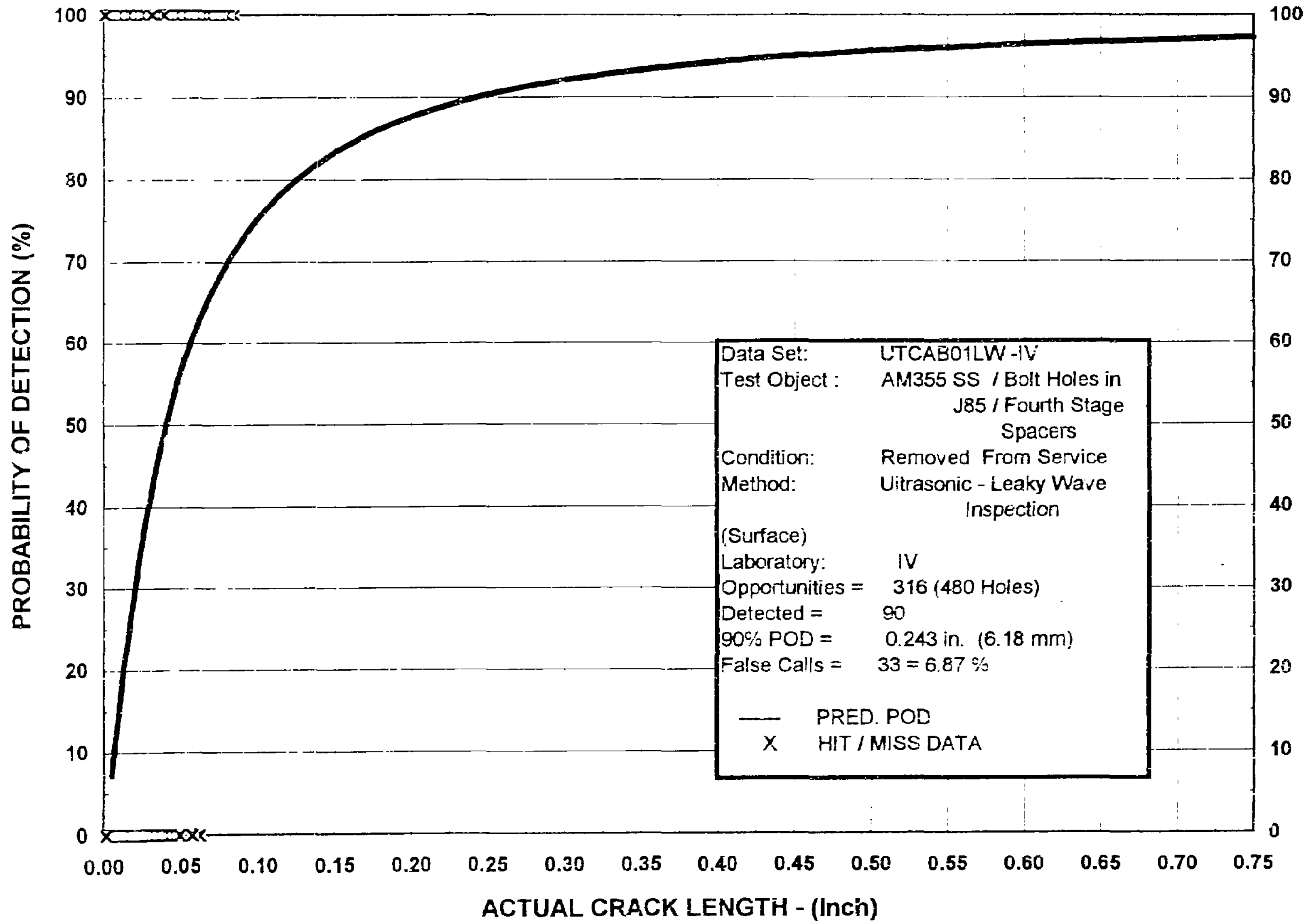
UTCAA01LW-IV
(ORG. IV)

UT- 05 (4)	DATA SET DISCRIPTION
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Bolt holes in J85 / Fourth stage spacers; 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Ultrasonic Inspection - Leaky Wave
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Immersion Inspection / Manual Read-out
DATA SET IDENTIFIERS:	UTCAB01LW -IV
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	IV: 480 holes / 316 cracks
DETECTED:	ORG IV: 90
FALSE CALLS:	ORG IV: 33 = 6.87 %
REFERENCE:	LTR-ST-1961 Fahr. A., D. Forsyth, M. Bullock and W. Wallace, **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**, February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation



This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.

90% POD ORG IV: 0.243 in. (6.18 mm)

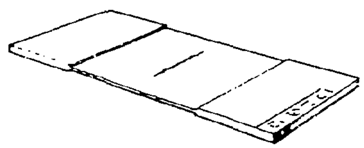


UT - 05 (4) ULTRASONIC INSPECTION OF GAS TURBINE ENGINE SPACERS

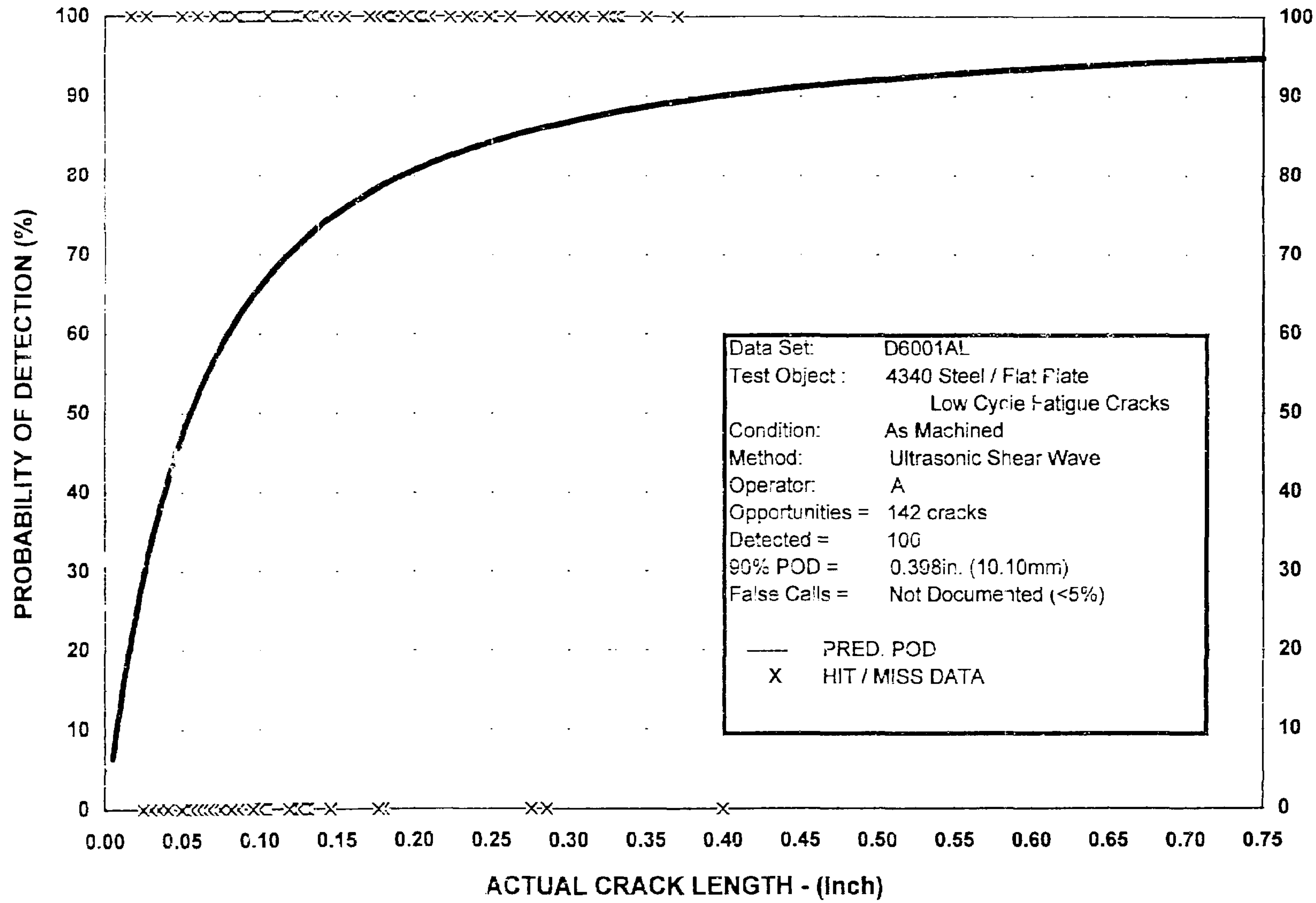
06/95

UTCAB01LW-IV
(ORG. IV)

D6000(2)L	DATA SET DESCRIPTION
METHOD:	Ultrasonic Surface Wave
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches. cracks on both sides
NDE PROCEDURE:	Ultrasonic surface wave @5MHz, 0.375" flat transducer, Immersion C-scan
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation. growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.060 and 0.250 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02."After Etch", -03,B1"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIER:	D6001-A,B,C; D6003-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	176 Cracks -Variation in the number inspected during each sequence
DETECTED:	D6001 - A = 100/142 B=101/142, C= 102/142; D6003 - A= 107/176, B= 106/176, C= 111/176
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098. Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen. **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner. NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.

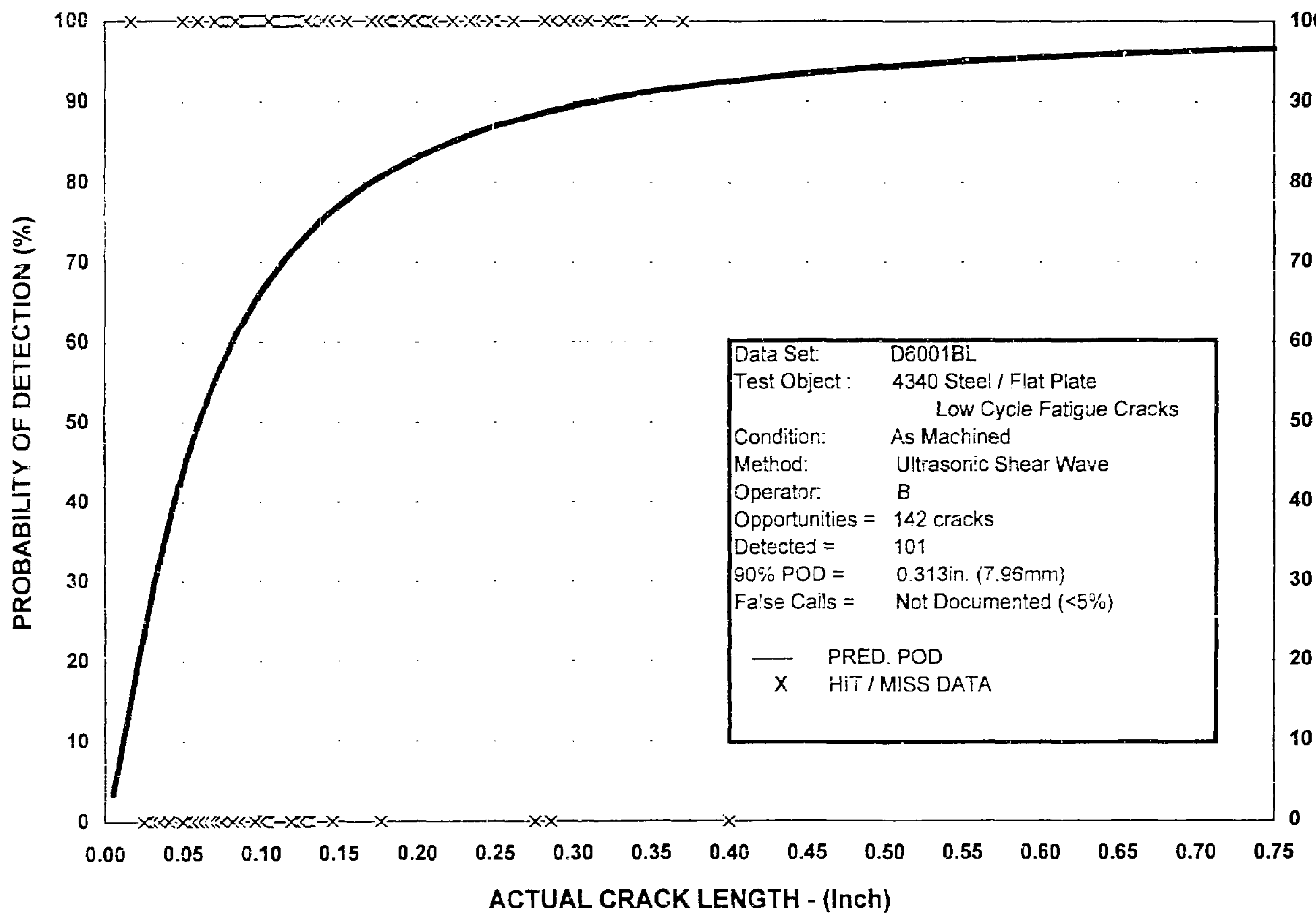


90% POD	"AS MACHINED"	"AFTER PROOF"
	A= 0.398in. (10.10mm)	A= 0.573in. (14.55mm)
	B= 0.313in. (7.96mm)	B= 0.427in. (10.85mm)
	C= 0.327in. (8.31mm	C= 0.449in. (11.40mm)



D6000(2) ULTRASONIC SHEAR WAVE INSPECTION
OF 4340 STEEL PANELS
9/96 - D6001AL

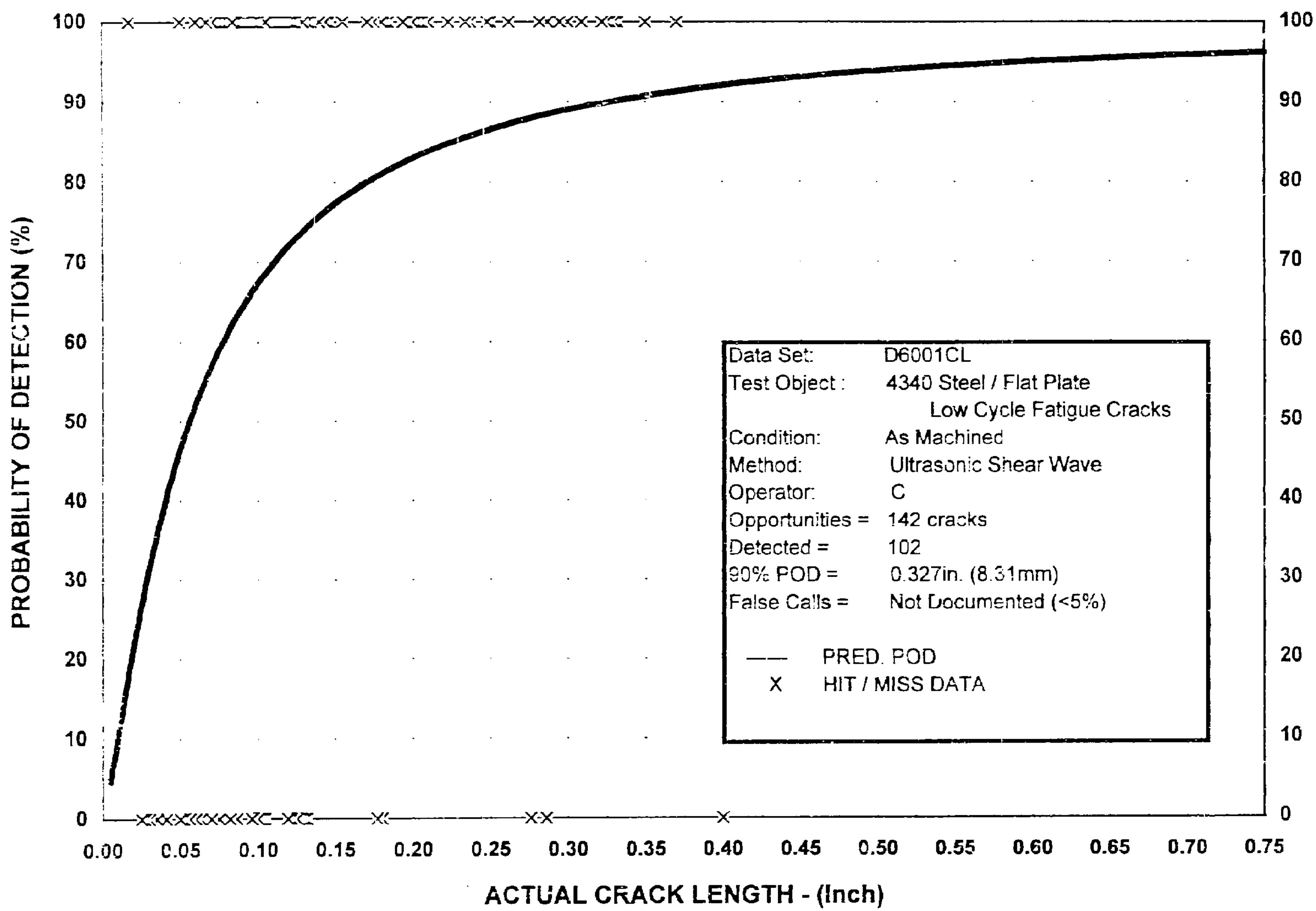
D6001AL
AS MACHINED - OPERATOR A



D6000(2) ULTRASONIC SHEAR WAVE INSPECTION
OF 4340 STEEL PANELS

9/95 - D6001BL

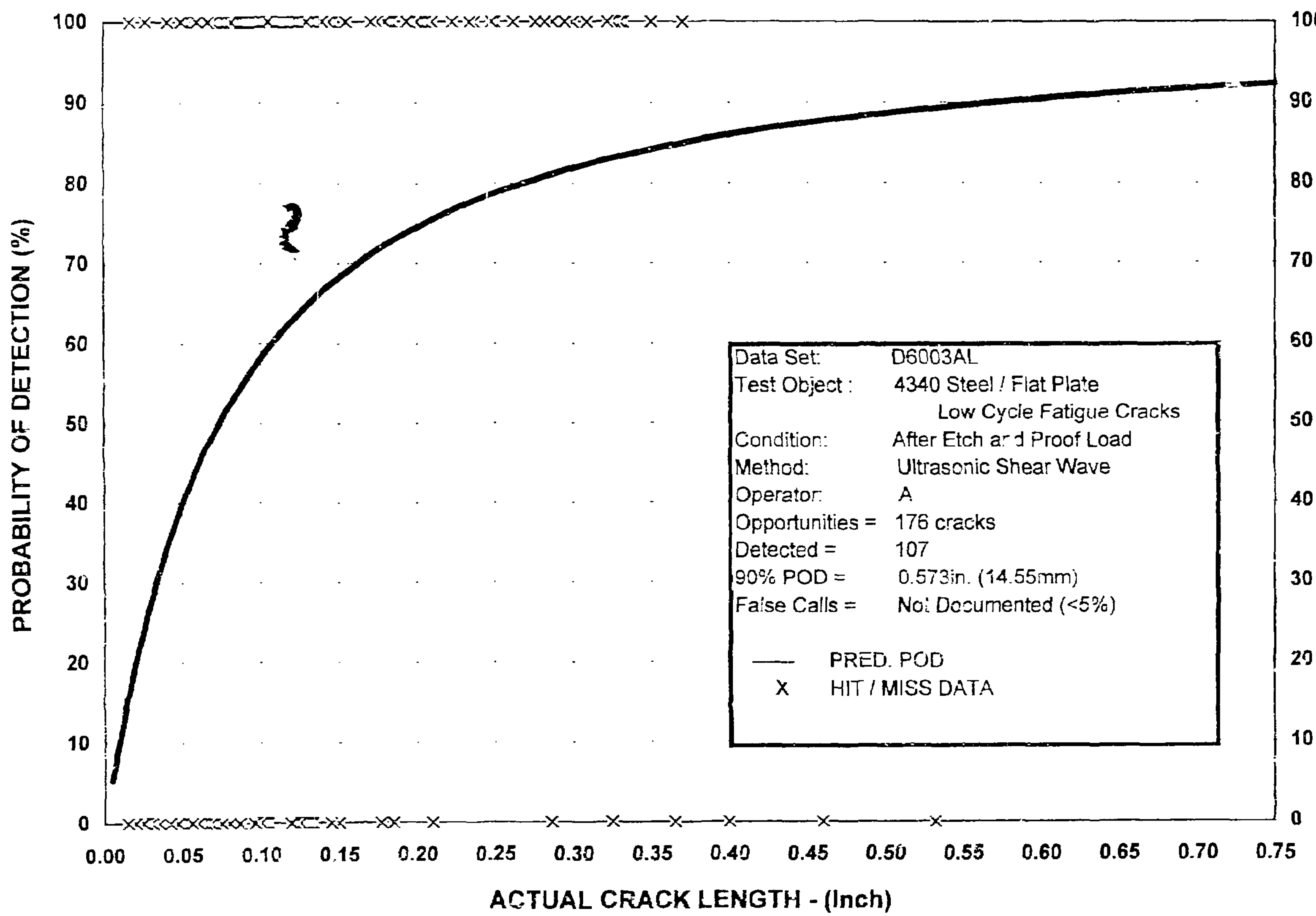
D6001BL
AS MACHINED - OPERATOR B



D6000(2) ULTRASONIC SHEAR WAVE INSPECTION
OF 4340 STEEL PANELS

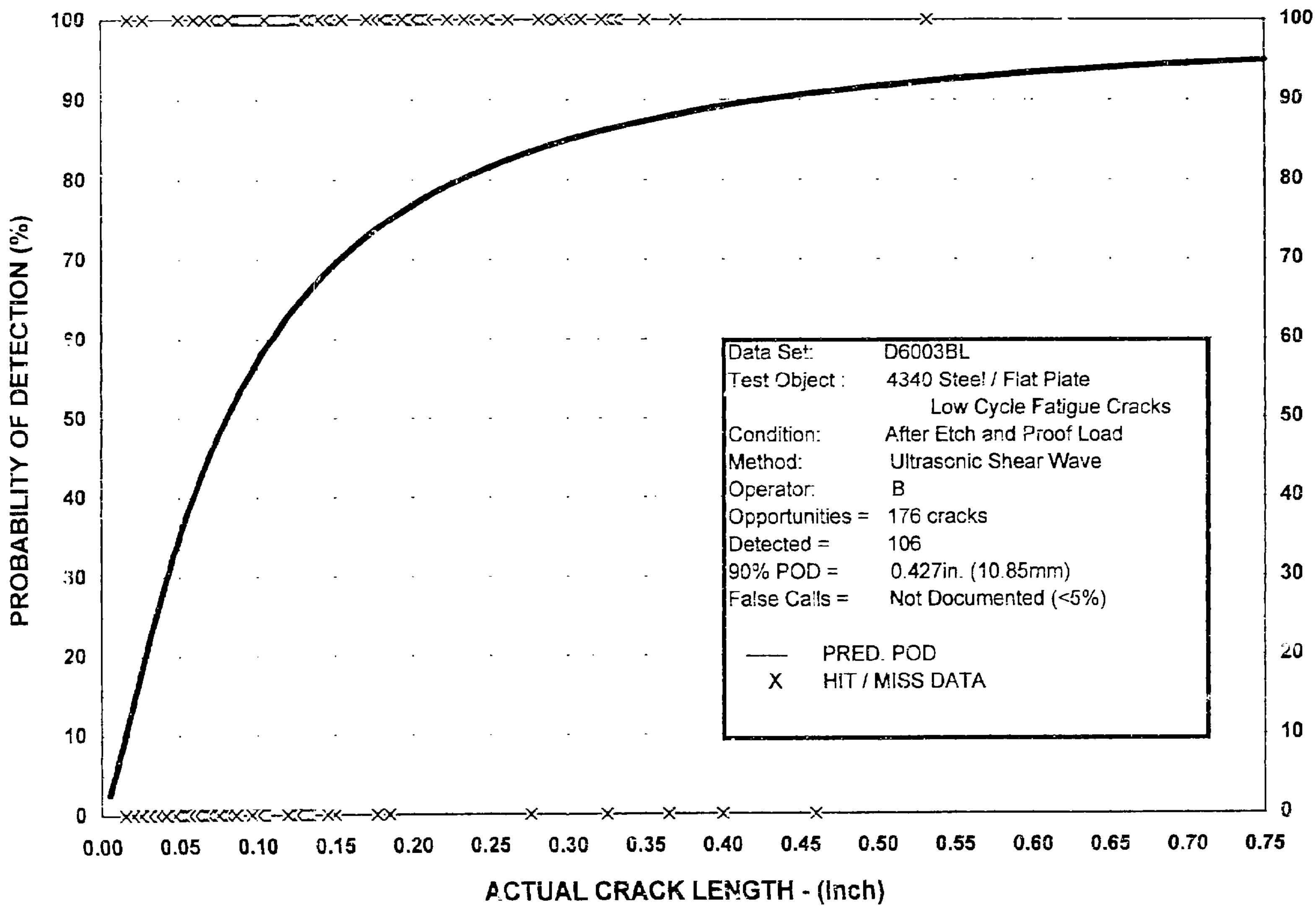
9/96 - D6001CL

D6001CL
AS MACHINED - OPERATOR C



D6000(2) ULTRASONIC SHEAR WAVE INSPECTION
OF 4340 STEEL PANELS
9/96 - D6003AL

D6003AL
AFTER ETCH AND PROOF LOAD - OPERATOR A

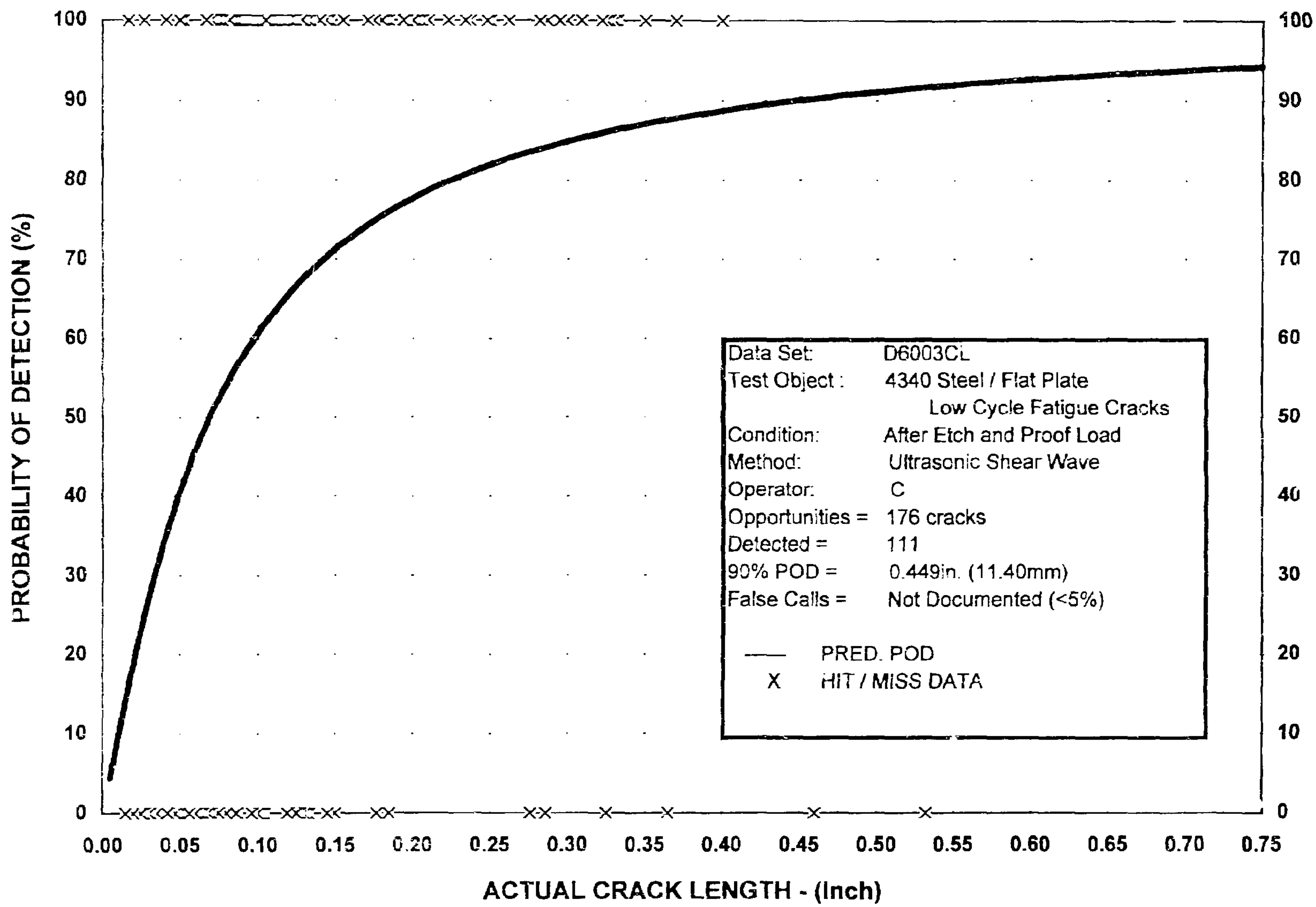


D6000(2) ULTRASONIC SHEAR WAVE INSPECTION OF 4340 STEEL PANELS

9/96 - D6003BL

D6003BL

AFTER ETCH AND PROOF LOAD - OPERATOR B

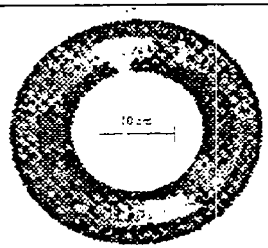


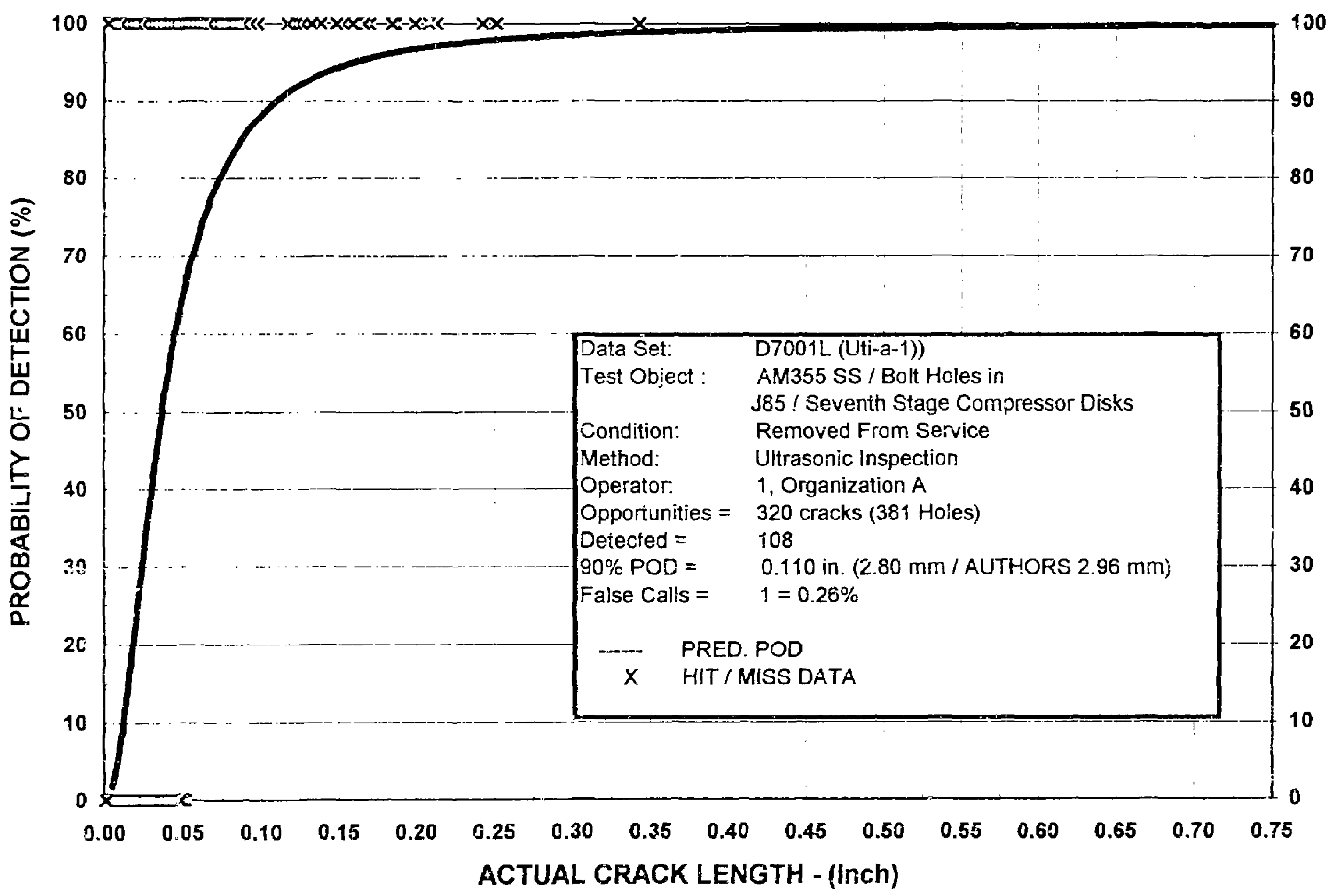
D6000(2) ULTRASONIC SHEAR WAVE INSPECTION OF 4340 STEEL PANELS

9/96 - D6003CL

D6003CL

AFTER ETCH AND PROOF LOAD - OPERATOR C

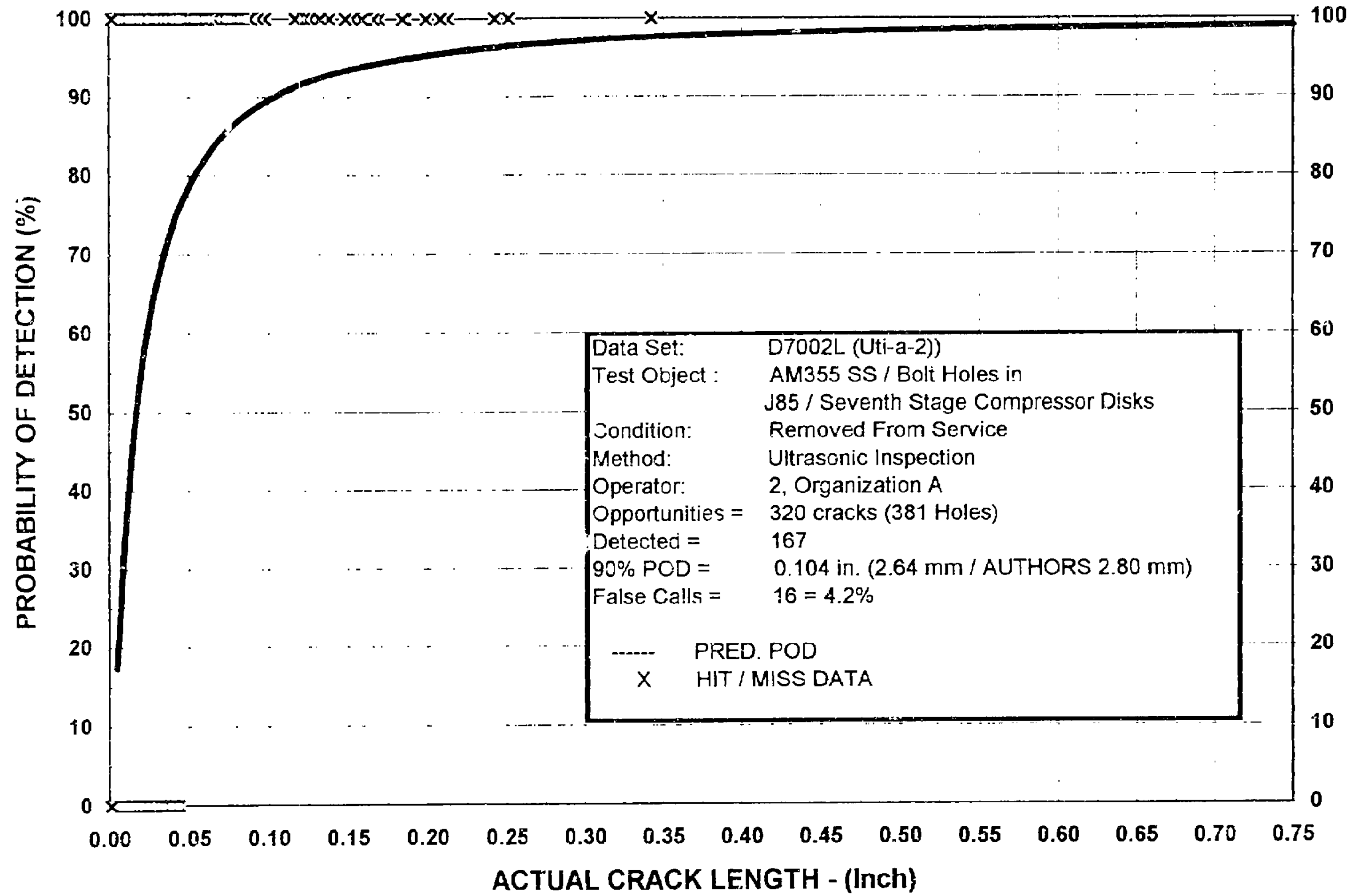
D7000(7)L	DATA SET DESCRIPTION
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Bolt holes in J85 / Seventh stage compressor disks; 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	Ultrasonic Shear Wave / Leaky Wave
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual and automated
DATA SET IDENTIFIERS:	D7001L, D7002L; and D7003L
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	381 Holes / 320 cracks
DETECTED:	D7001L - 108, D7002L - 167; and D7003L - 82
FALSE CALLS:	D7001L - 1, D7002L - 16; and D7003L - 0
REFERENCE:	LTR-ST-2055, D.S. Forsyth and A. Fahr, **The Sensitivity and Reliability of NDI Techniques for Gas Turbine Components Inspection and Life Prediction**,
DATE:	August, 1996.
WORK SPONSOR:	Department of National Defence, DAS Eng 6-2.
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	The maximum likelihood method of curve fitting used in this databook differs slightly from the algorithm used by the authors. The authors calculated values are shown for reference.
	Maximum differences are shown for those data sets with the greatest variance. The authors noted difficulties fitting such data to the model.
	90% POD ORG A, Op. 1: 0.110 in. (2.80 mm / Authors - 2.96 mm)
	ORG A, Op 2: 0.104 in. (2.64 mm / Authors - 2.80mm)
	ORG C: 0.061 in. (1.56 mm / Authors - 1.96 mm)



D7001L Service Induced Cracks
ORGANIZATION A, OPERATOR 1

D7000(7) ULTRASONIC INSPECTION OF BOLT HOLES

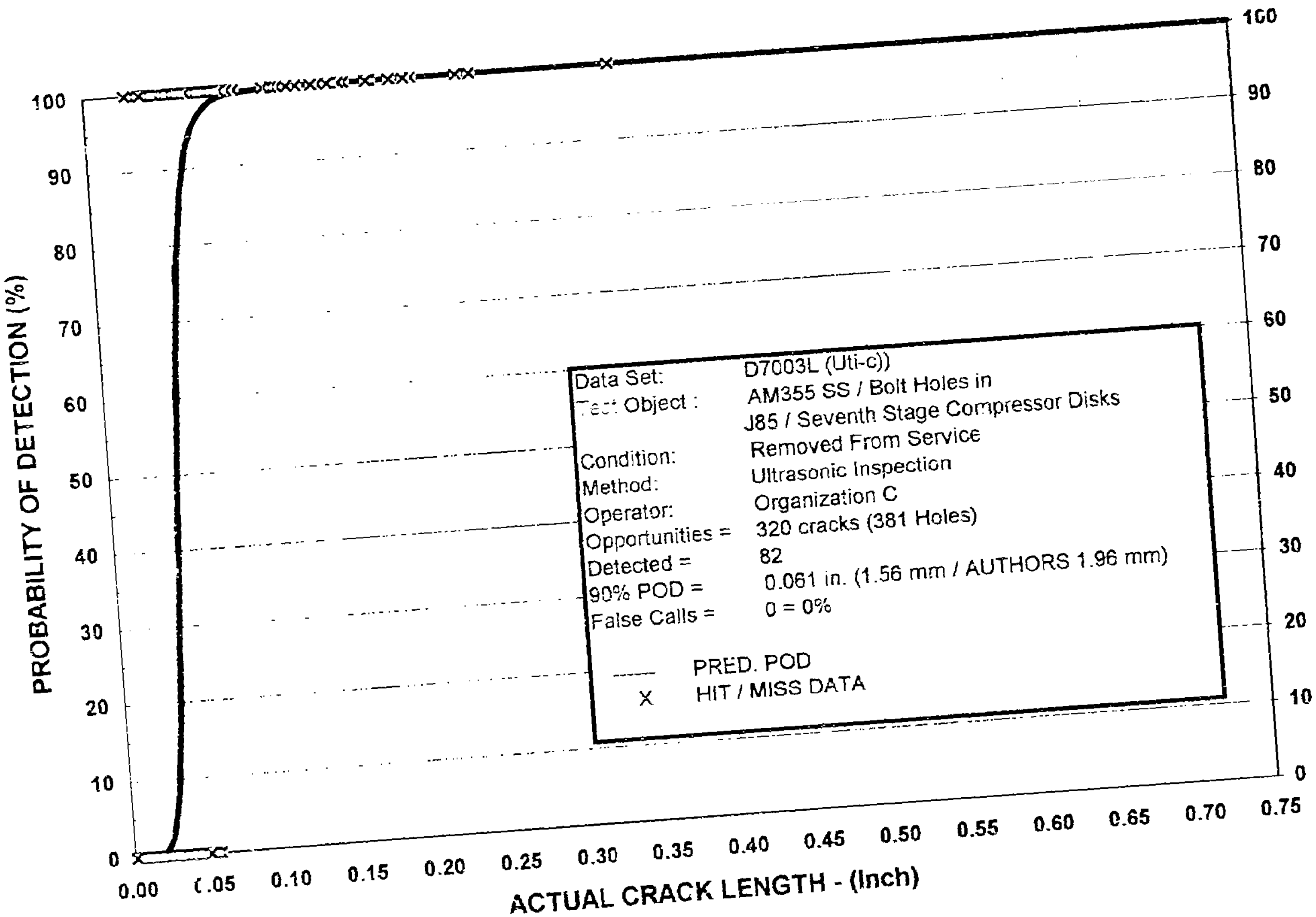
9/96 - D7001L



D7002L Service Induced Cracks
ORGANIZATION A, OPERATOR 2

D7000(7) ULTRASONIC INSPECTION OF BOLT HOLES

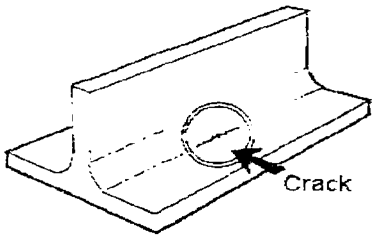
9/96 - D7002L



D7003L Service Induced Cracks
ORGANIZATION C

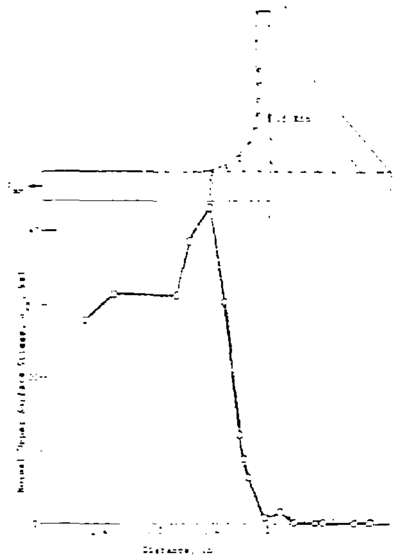
D7000(7) ULTRASONIC INSPECTION OF BOLT HOLES

9/96 - D7003L

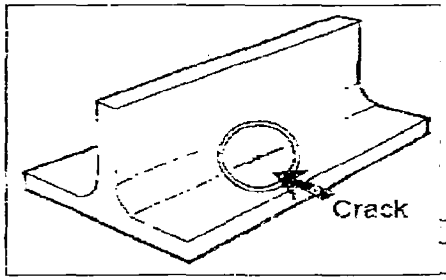
D8000(3)L,D	**DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS**
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (D8001 and D8002); Stringers Riveted to a Flat Plate (D8003)
NDE PROCEDURE:	Ultrasonic Shear Wave inspection, 10 Mhz; 0.625 in. diameter element.
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	Base Plate- 0.250 inch nominal / Webs - 0.250 inch nominal
TEST OBJECT CONDITION:	D8001,"As Machined"; D8002,"After Etch"; D8003, Stringers cut from panel and riveted to a flat plate.
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Raster scan with tooling aids
DATA SET IDENTIFIER:	D8001(3)L,D; D8002(3)L,D; D8003(3)L,D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	417 Cracks
DETECTED:	D8001(3)L/D = 330; D8002(3)L/D = 327 ; D8003(3)L/D = 270 *(Combined data for 3 operators)*
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	146 flaws were induced in 46 panels (both sides of the web). Four blank panels; included:Total of 50panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method. The program provided an assessment of the effects of part geometry on inspection capabilities. 90% POD Length - "AS MACHINED" A= 0.340 IN. "AFTER ETCH" A= 0.219 in. "RIVETED CONFIGURATION" A= 0.365 IN. 90% POD Depth - "AS MACHINED" A= 0.052 in. "AFTER ETCH" A= 0.042 in. "RIVETED CONFIGURATION" A= 0.055 in.
Test Specimen Descriptions on the following page!	

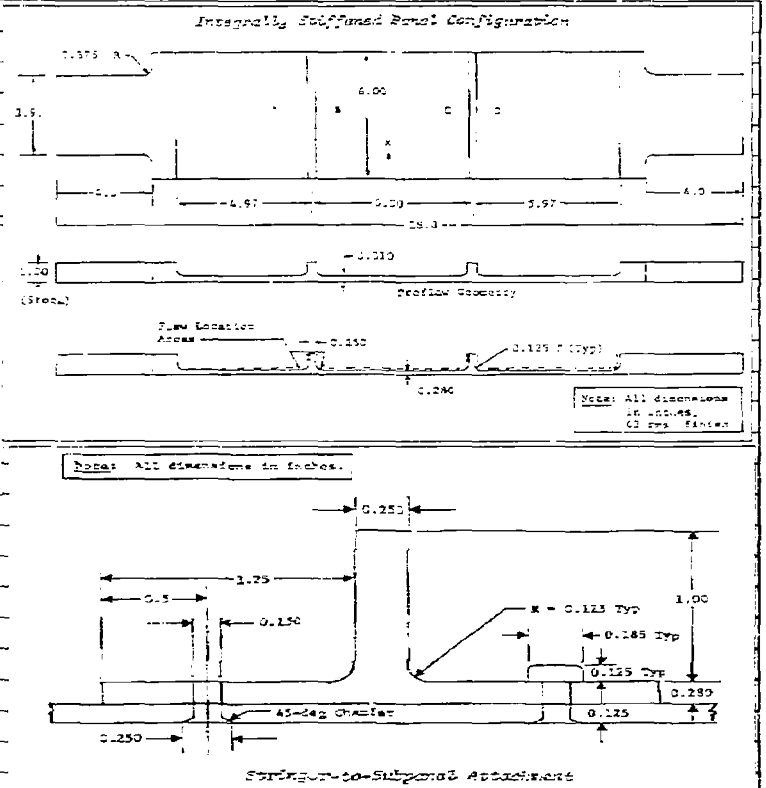
D8000(3)L,D	**DATA SET DESCRIPTION - CRACK LENGTH AND DEPTH IN STRINGERS**
METHOD:	Ultrasonic Inspection
TEST OBJECT TYPE:	Machined, Stringer Stiffened Panels (D8001 and D8002); Stringers Riveted to a Flat Plate (D8003)
NDE PROCEDURE:	*Ultrasonic Shear Wave inspection, 10 Mhz: 0.325 in. diameter element.*

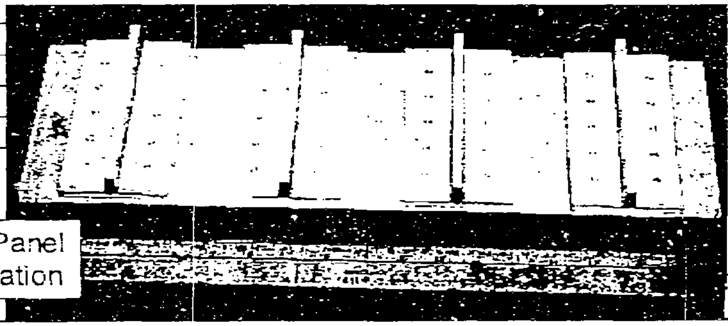
TEST SPECIMEN DESCRIPTORS



Anticipated Surface Stress Distribution for and axial load (panel plane)

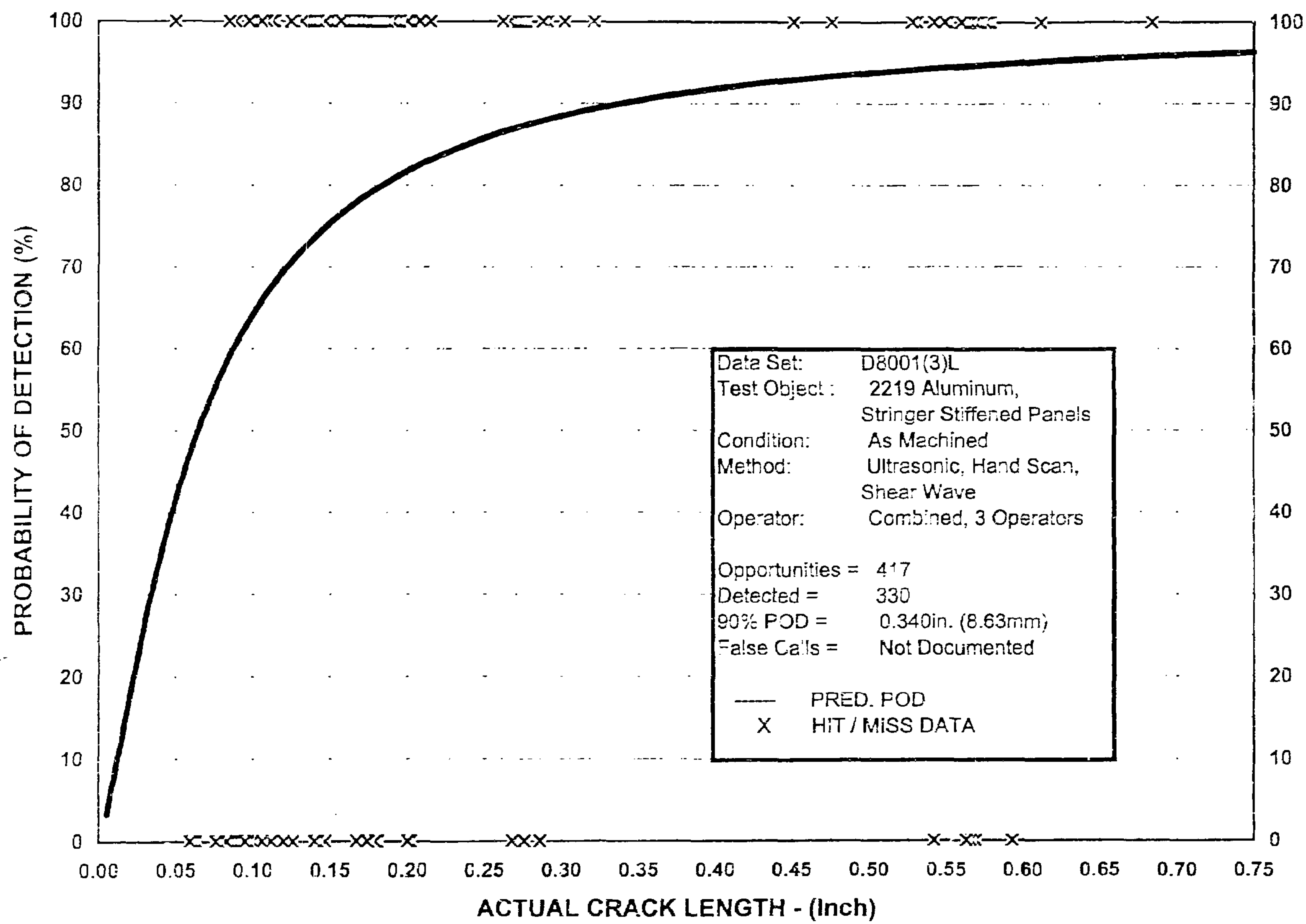






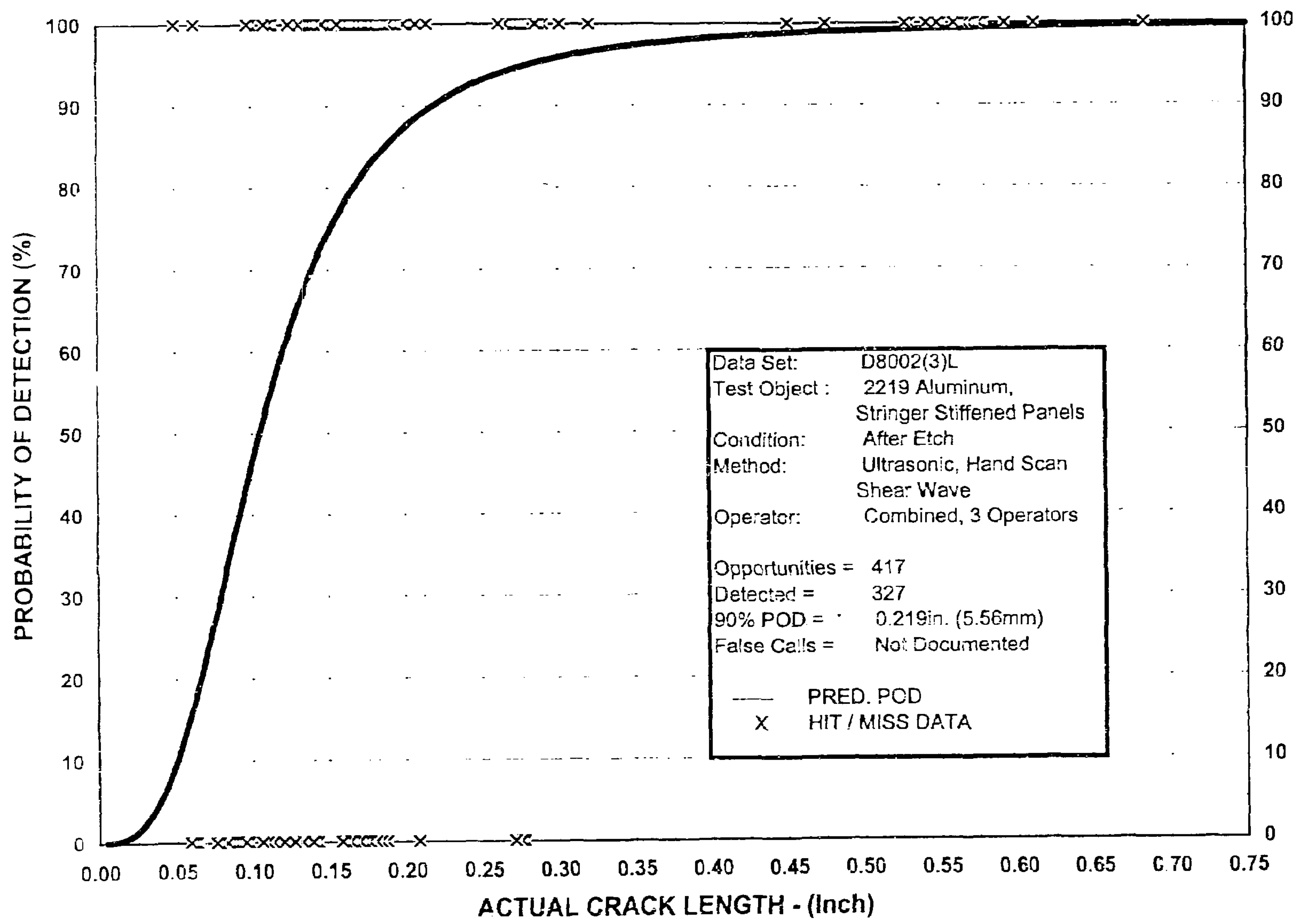
Riveted Panel Configuration

STRINGER STIFFENED PANELS AND RIVETED STIFFENERS ON A FLAT PANEL SUBSTRATE



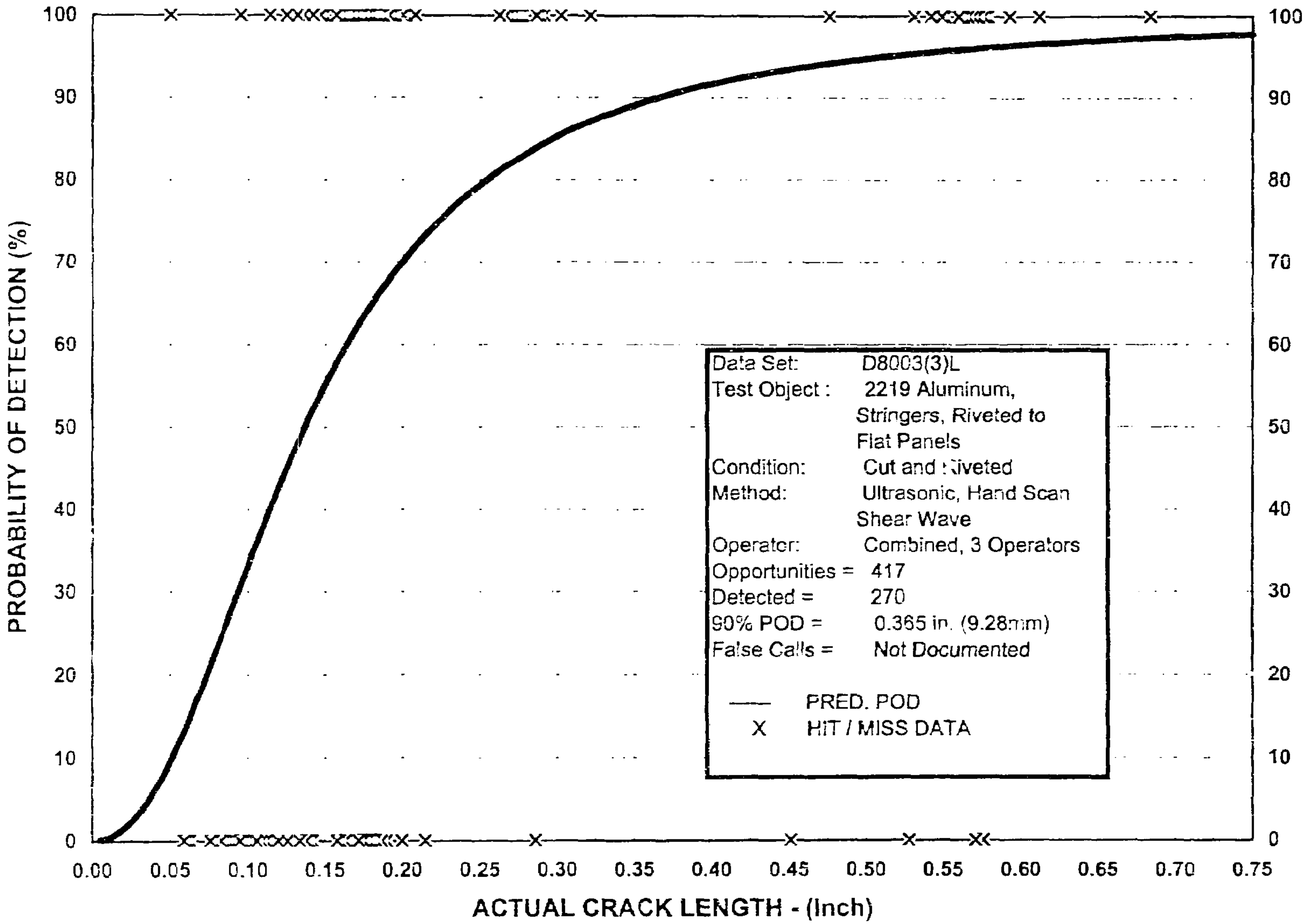
D8001(3)L
6/97 -D8001(3)L

Ultrasonic, Hand Scan, Shear Wave- 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



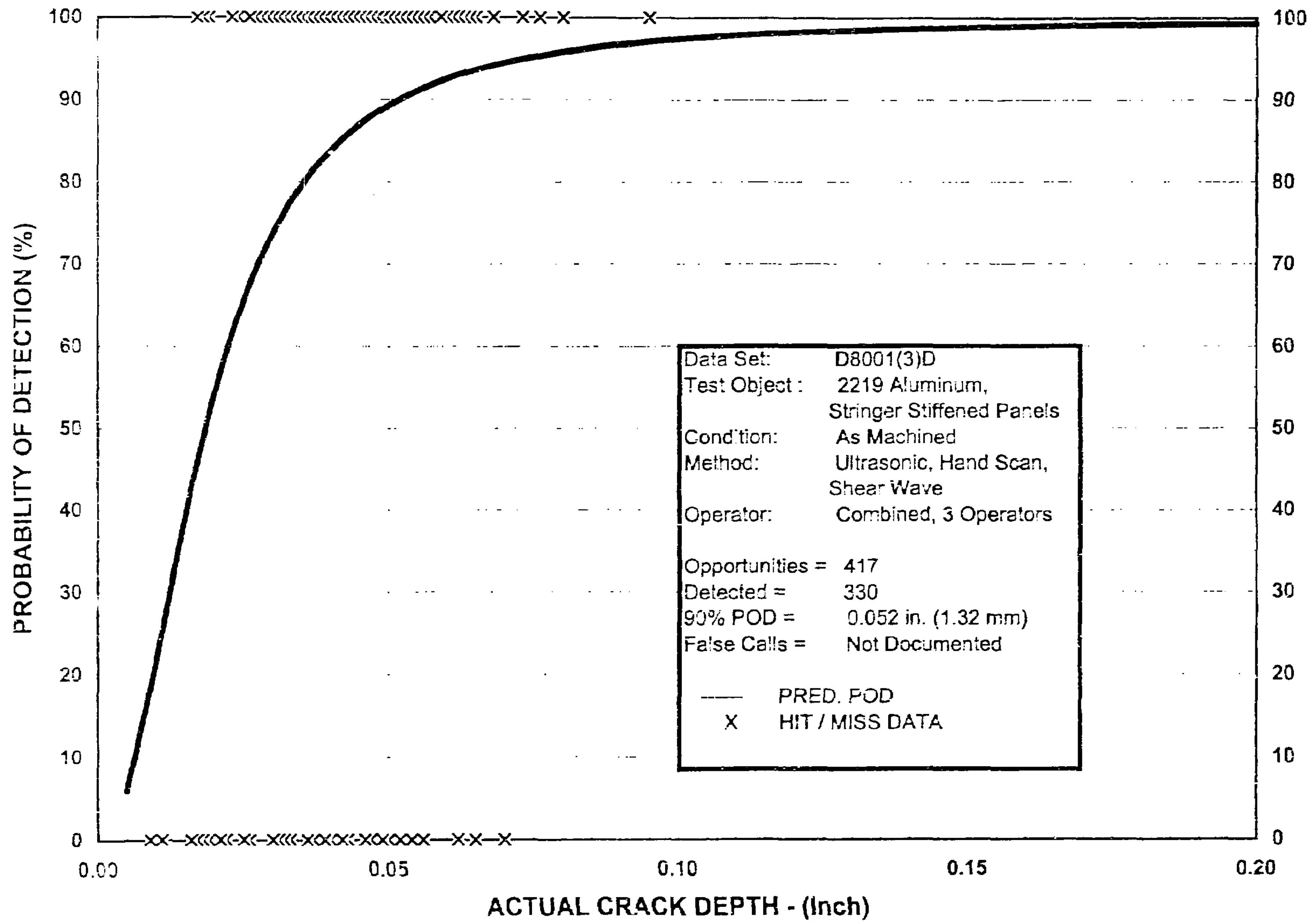
D8002(3)L
6/97 -D8002(3)L

Ultrasonic, Hand Scan, Shear Wave- 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch



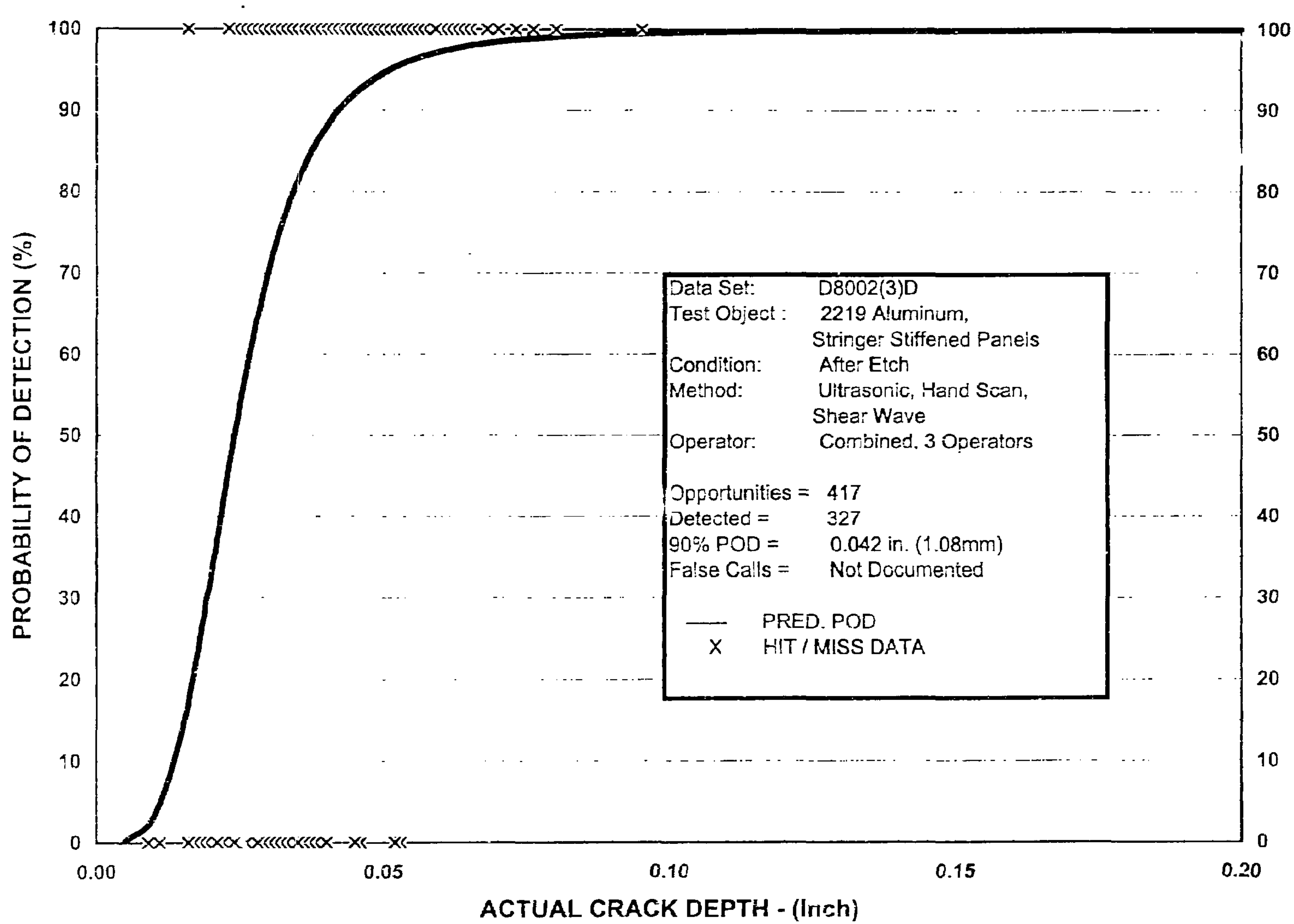
D8003(3)L
6/97 -D8003(3)L

Ultrasonic, Hand Scan, Shear Wave- 3 Operators
2219 Aluminum, Stringers, Riveted to Flat Panels



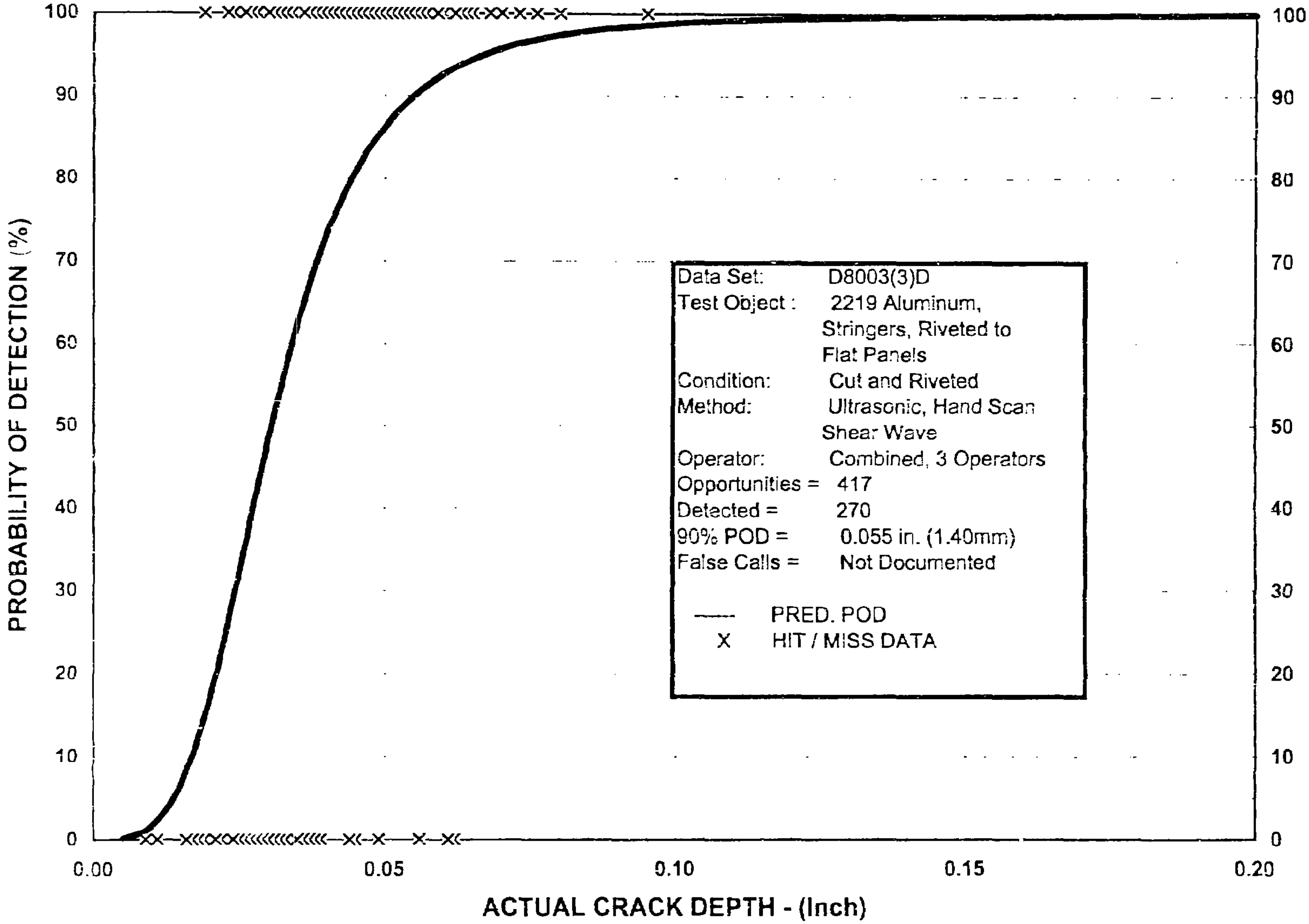
D8001(3)D
6/97 -D8001(3)D

Ultrasonic, Hand Scan, Shear Wave - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, As Machined



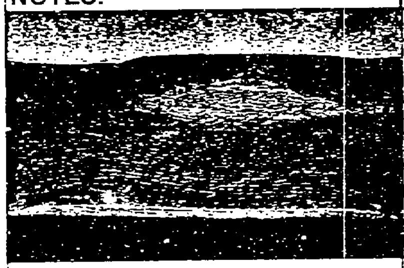
D8002(3)D
6/97 -D8002(3)D

Ultrasonic, Hand Scan, Shear Wave - 3 Operators
2219 Aluminum, Stringer Stiffened Panels, After Etch

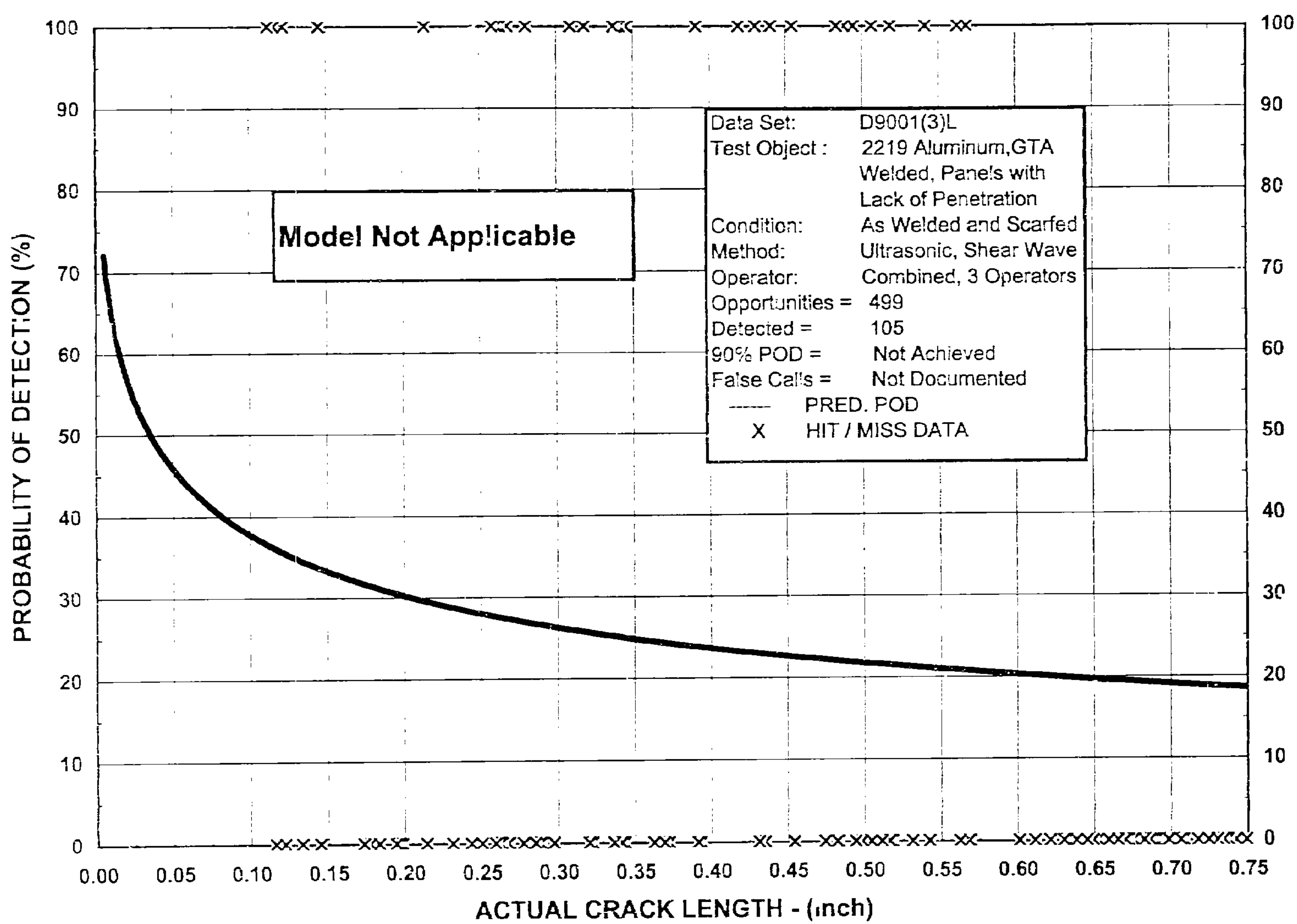


D8003(3)D
6/97 -D8003(3)D

Ultrasonic, Hand Scan, Shear Wave- 3 Operators
2219 Aluminum, Stringers, Riveted to Flat Panels

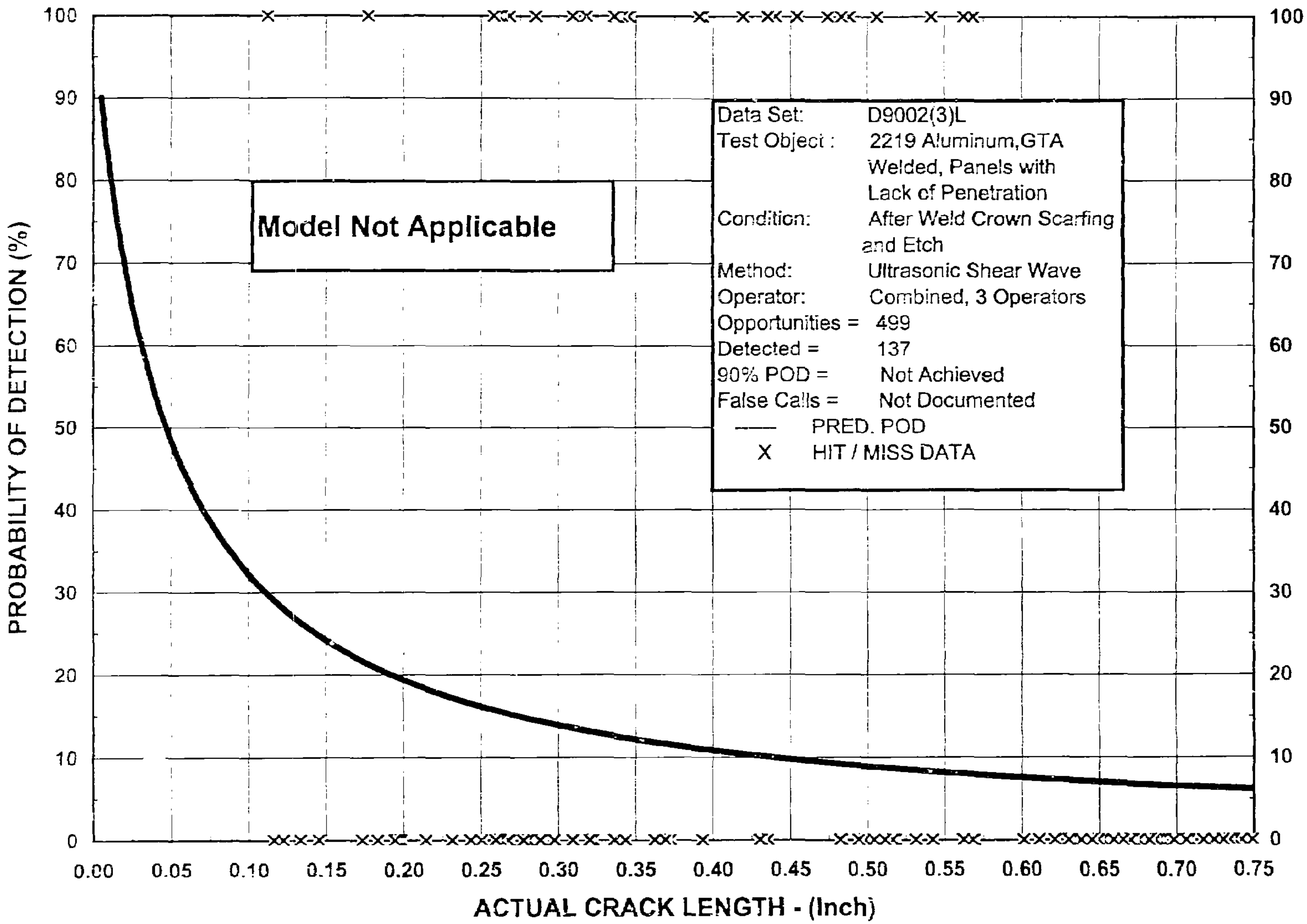
D9000(3)L,D	**DATA SET DESCRIPTION**
METHOD:	Ultrasonic Shear Wave Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. One pass from each panel surface.
NDE PROCEDURE:	Immersion - 10 MHZ, Pitch-Catch, 1/64 inch thru hole-Calibration; Gate-Thresh., -01 to 03; -04 to 06 + Align
ARTIFACT TYPE:	Lack of Penetration (LOP) defects / cracks, produced by the two pass weld process
ARTIFACT SHAPE:	Lune shapes with target lengths of 0.250, .500 and 1.00 inch and apex depths of 0.030 to 0.100 inch
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87: 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01 / 04,"As welded and Scarfed"; -02 / -05 "After Etch"; and -03 / -06, "After Proof Loading".
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Immersion Scan - C-scan Read-out
DATA SET IDENTIFIER:	D9001(3)L/D; D9002(3)L/D; D9003(3)L/D; D9004(3)L/D,D9005(3)L/D;and D9006(3)L/D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	166 Cracks / 498 opportunities. (Some defects / crack were lost during proof loading)
DETECTED:	-01(3)D/L = 105; -02(3)D/L = 137; -03(3)D/L= 455; - 04(3)D/L = 199; - 05(3)D/L = 203; - 06(3)D/L = 465
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**. October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	80 surface open flaws were induced in 43 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED"; "AFTER ETCH"; "AFTER PROOF"
	-01 L/D A= Not Achieved -02 L/D A= Not Achieved 03 L/D A= 0.110 in / N.A
	-04 L/D A= Not Achieved -05 L/D A= Not Achieved 06 L/D A= 0.025 in / 0.0125 in.
Test Specimen Descriptions	**Authors Note:** Variations in the ultrasonic data may be attributed primarily to variations in the alignment and warpage of the panels in a fixed immersion scanning system. -04; -05; and -06 were performed to provide clamping and improved alignment.
in AA000(3)L, Page 2	

ULTRASONIC SHEAR WAVE INSPECTION
WELD LACK OF PENETRATION (LOP) TEST SPECIMENS



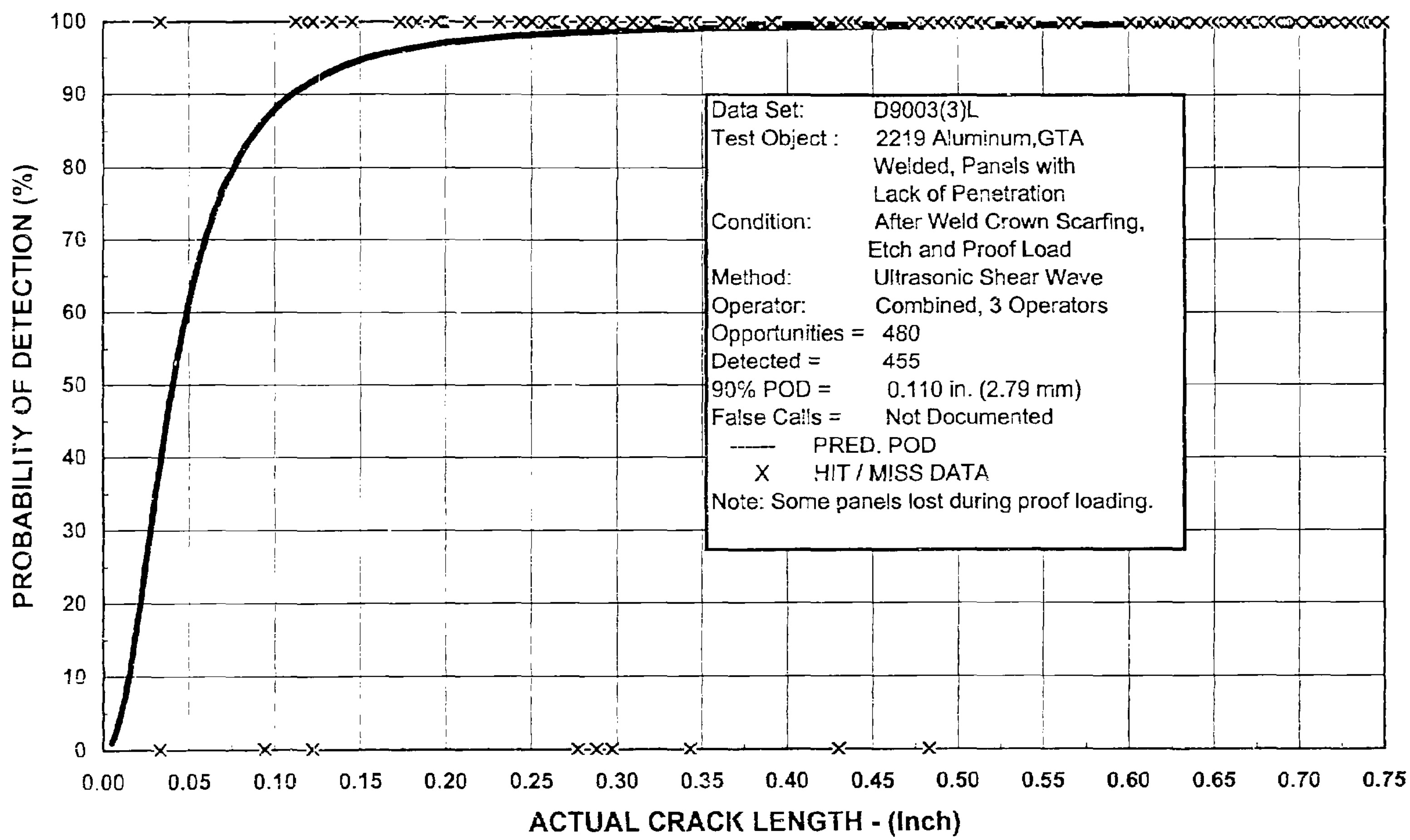
D9001(3)L
6/97 -D9001(3)L

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing



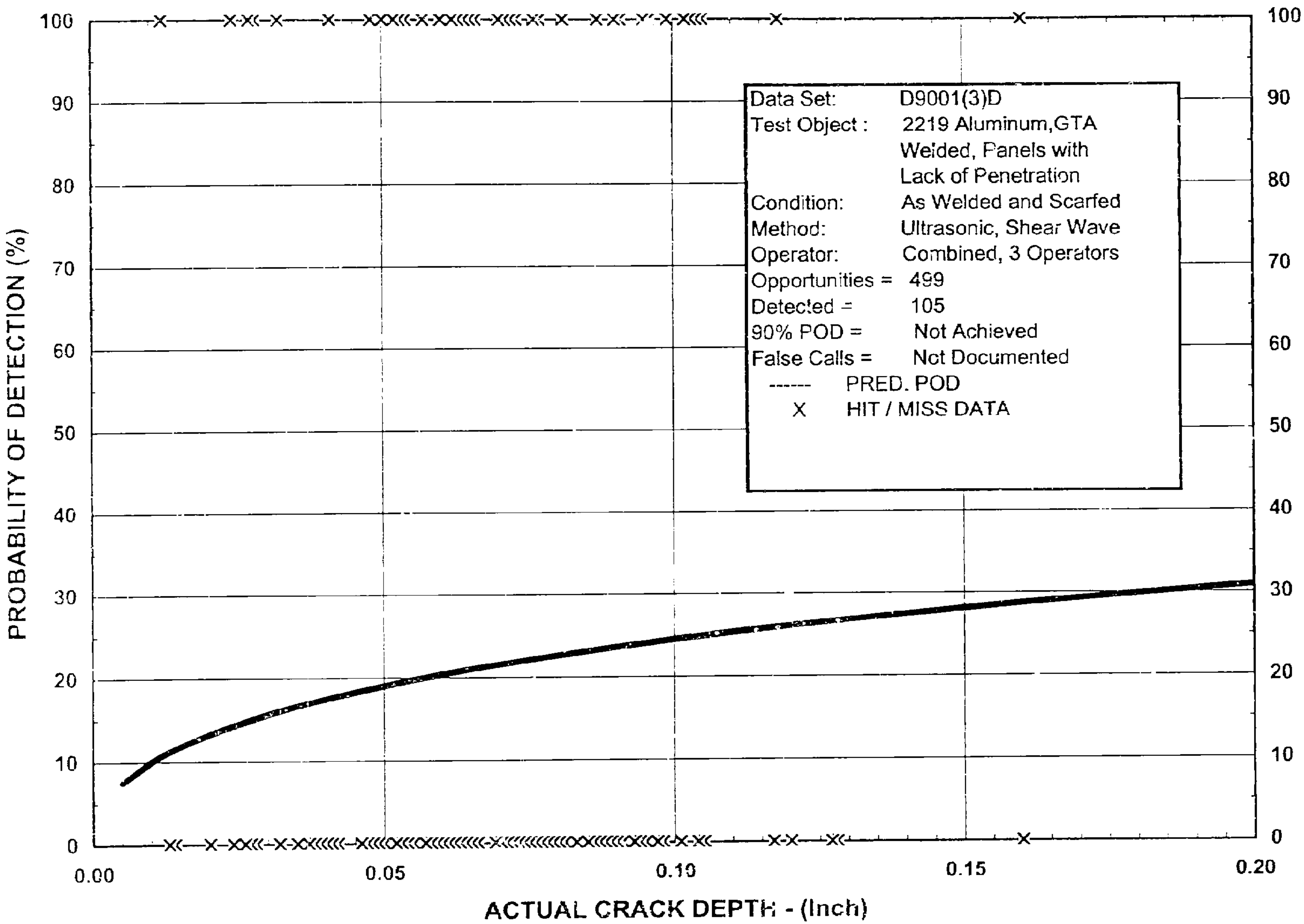
D9002(3)L
6/97 -D9002(3)L

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etch



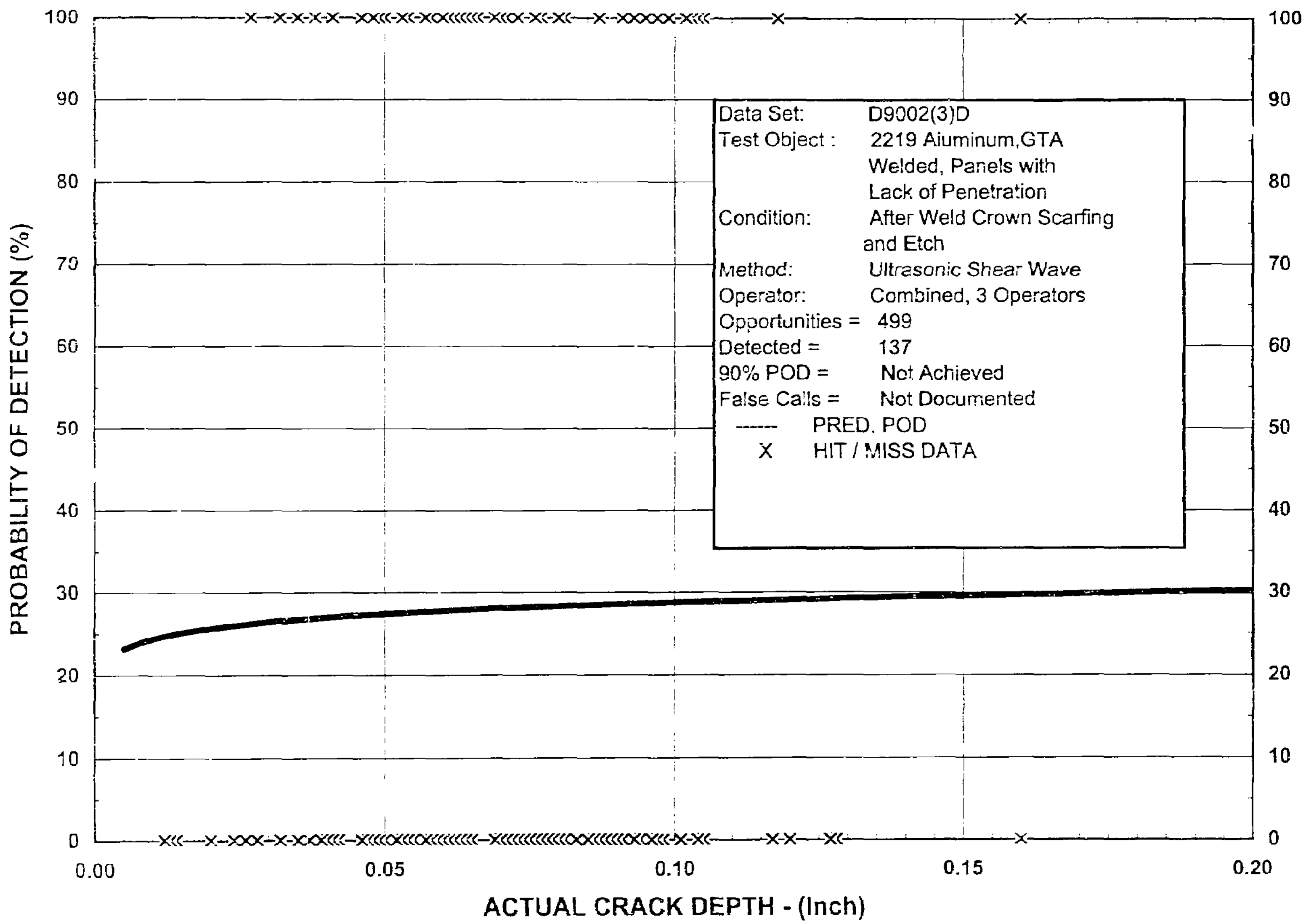
Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing, Etch and Proof Loading

D9003(3)L
6/97 -D9003(3)L



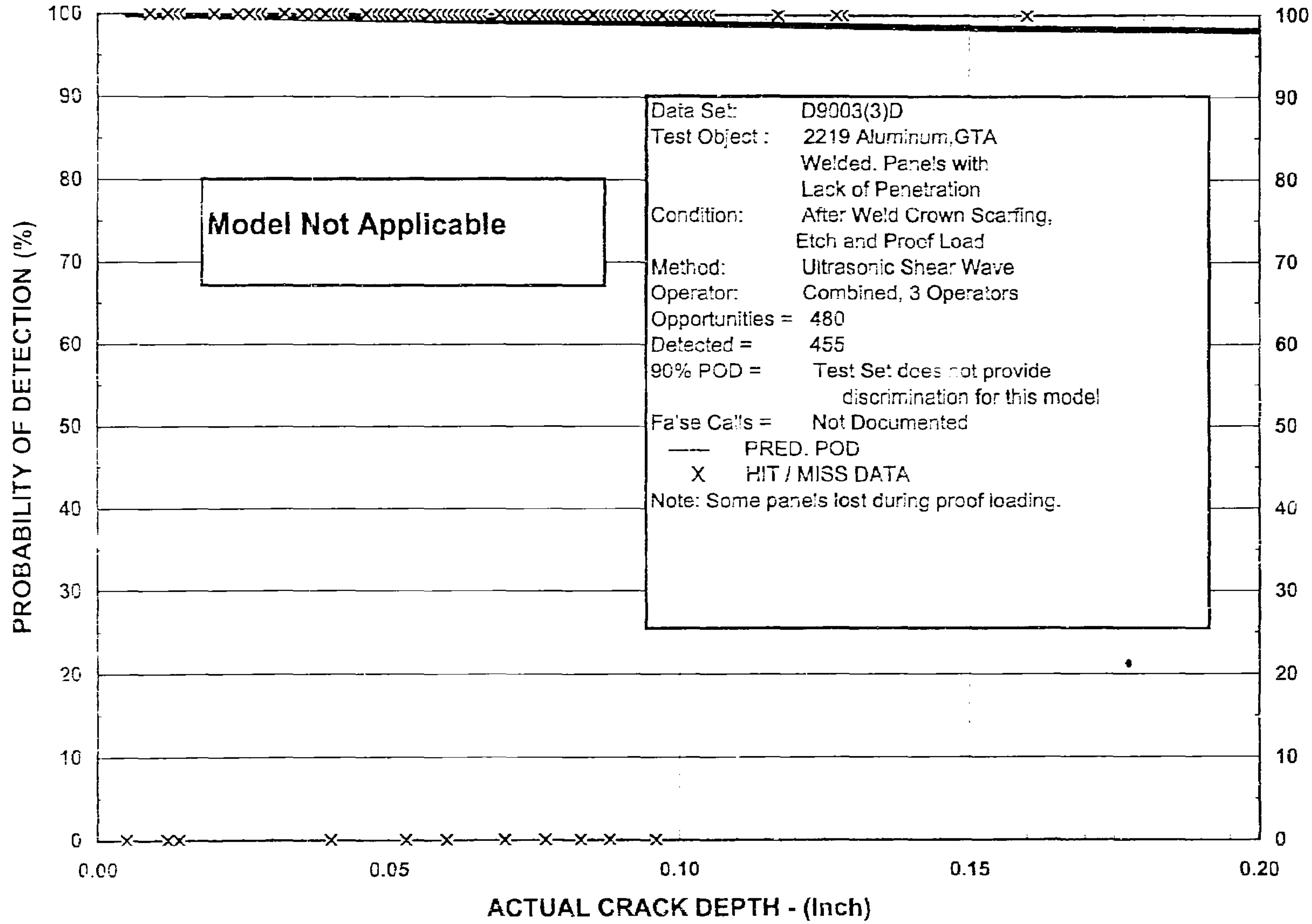
D9001(3)D
6/97 -D9001(3)D

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing



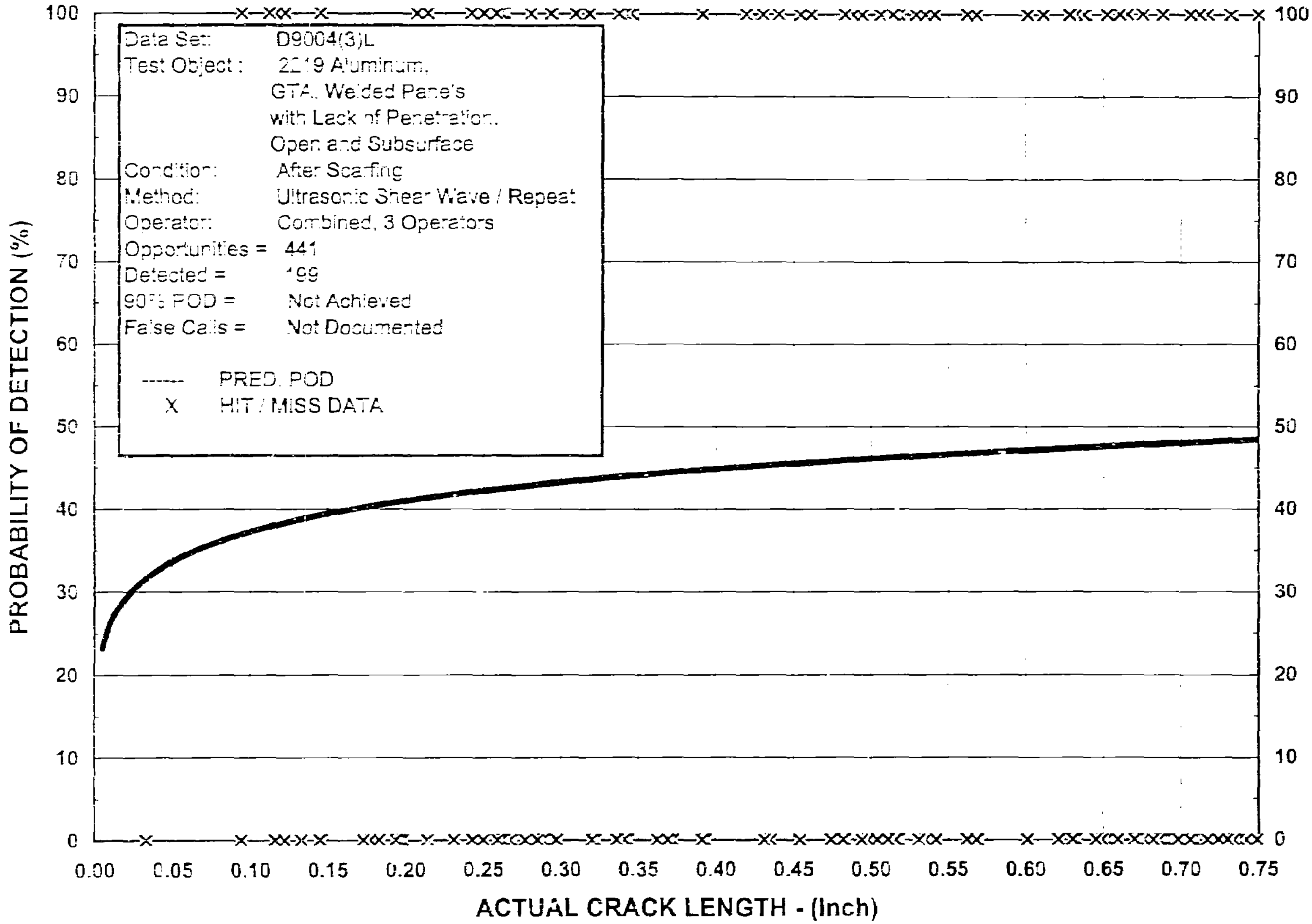
D9002(3)D
6/97 -D9002(3)D

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etch



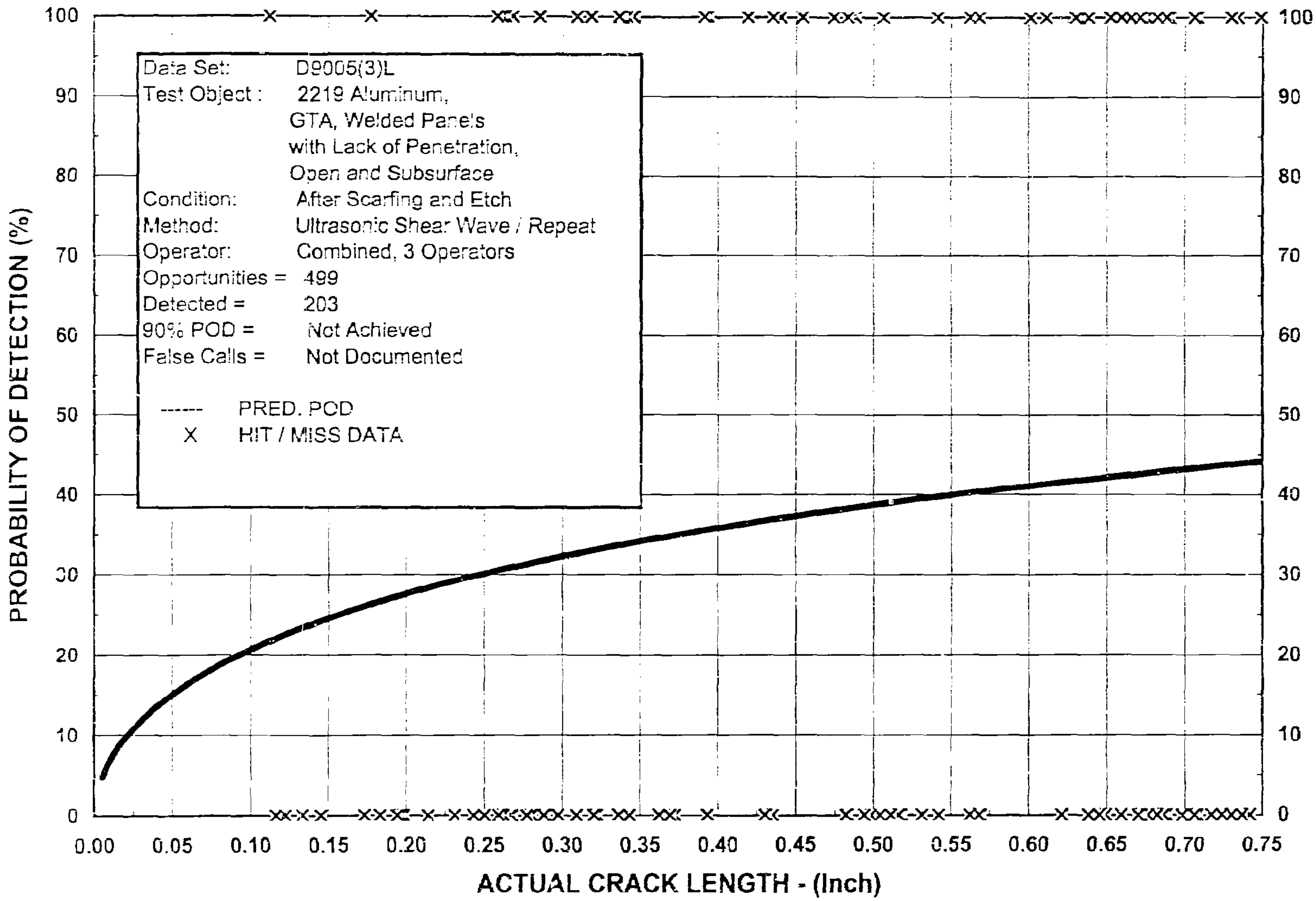
D9003(3)D
6/97 -D9003(3)D

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing



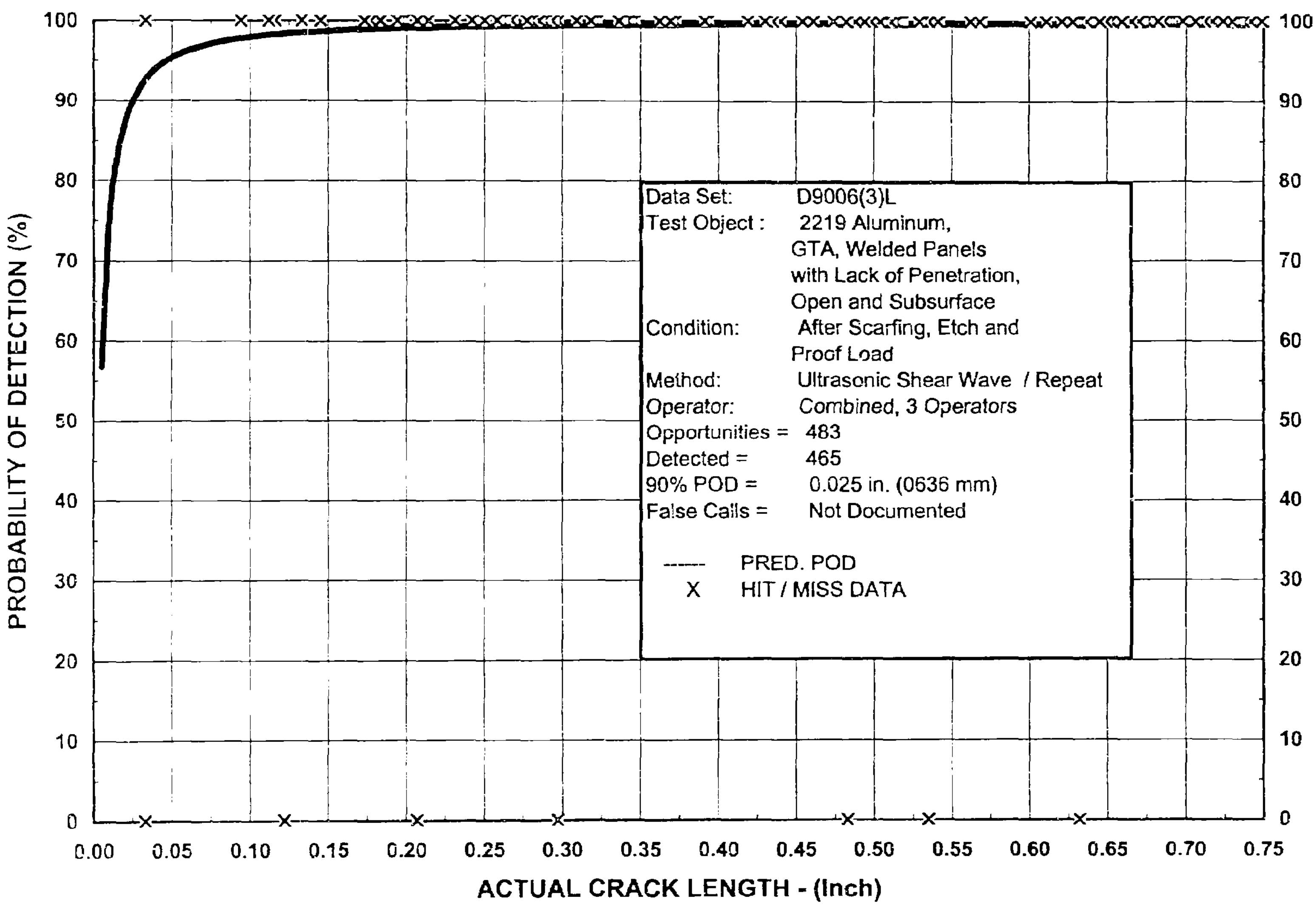
D9004(3)L
6/97 -D9004(3)L

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After Scarfing



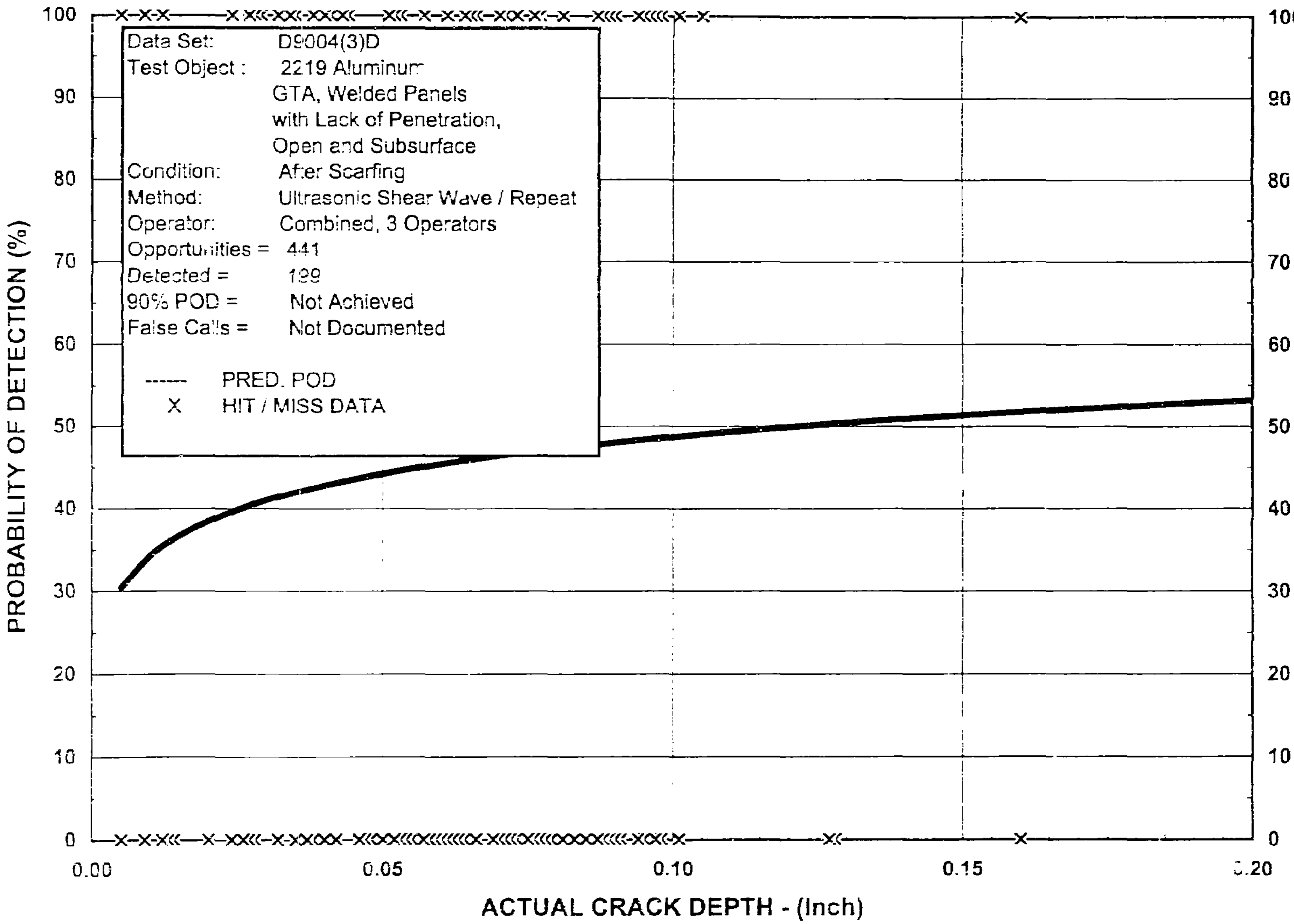
Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After and Etch

D9005(3)L
6/97 -D9005(3)L



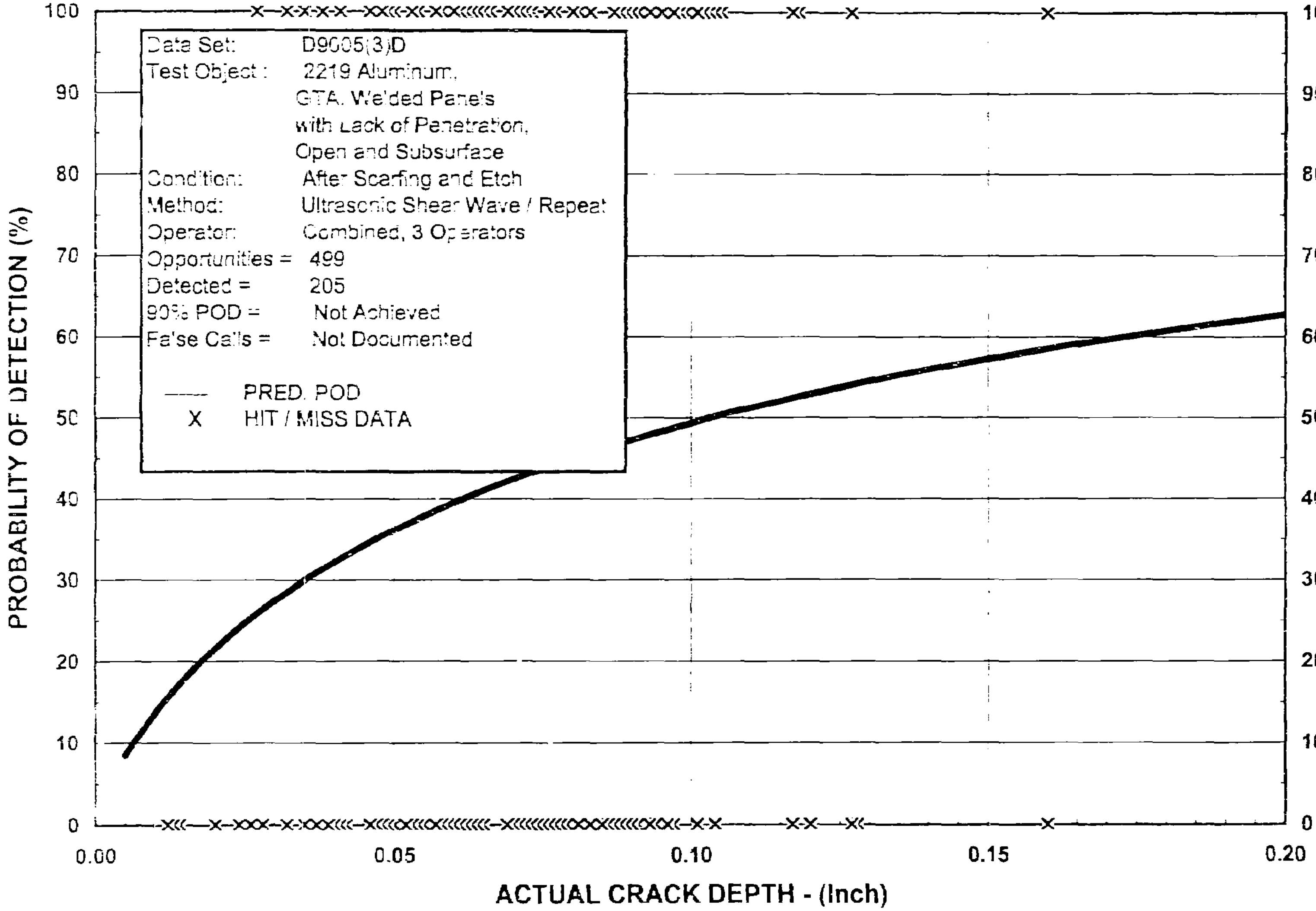
Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After Etch and Proof Load

D9006(3)L
6/97 -D9006(3)L



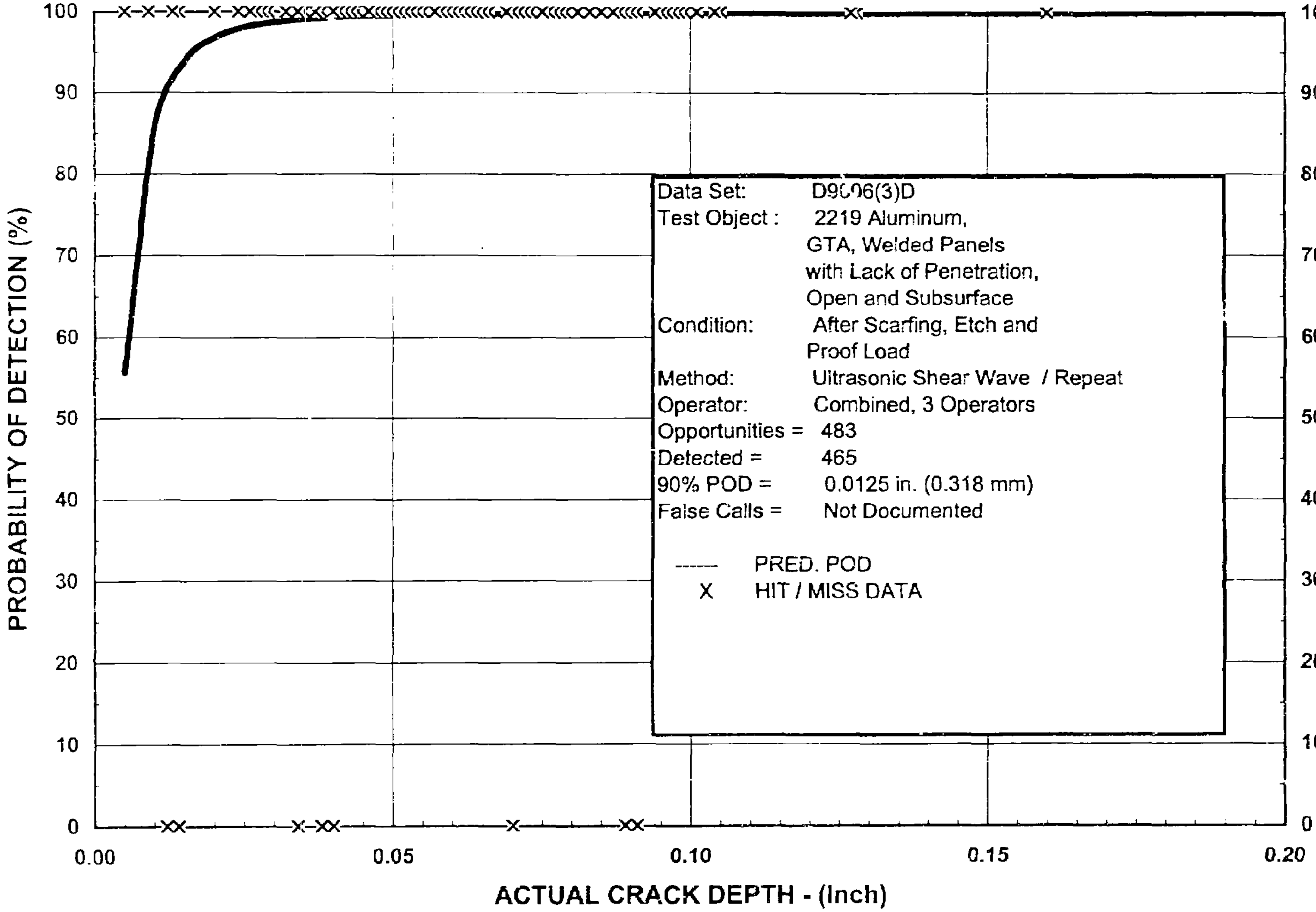
D9004(3)D
6/97 -D9004(3)D

Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After Scarfing



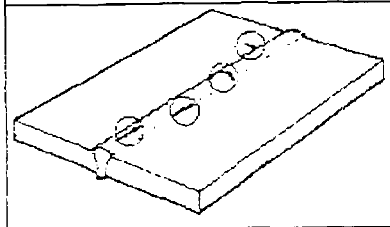
Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After and Etch

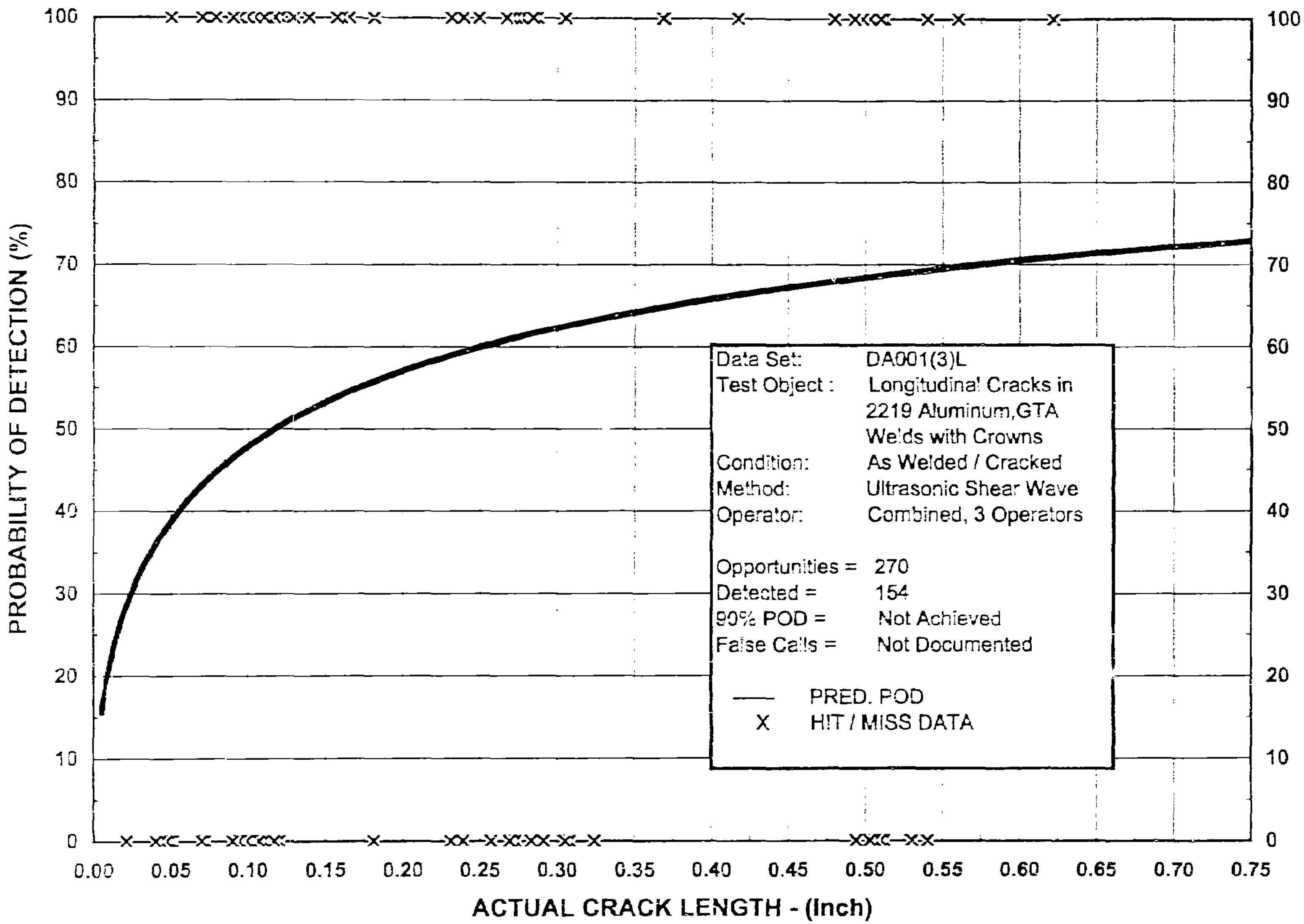
D9005(3)D
6/97 -D9005(3)D



Ultrasonic Shear Wave- 3 Operators
2219 Aluminum, GTA Welded Panels with Open and Subsurface Lack of Fusion, After Etch and Proof Load

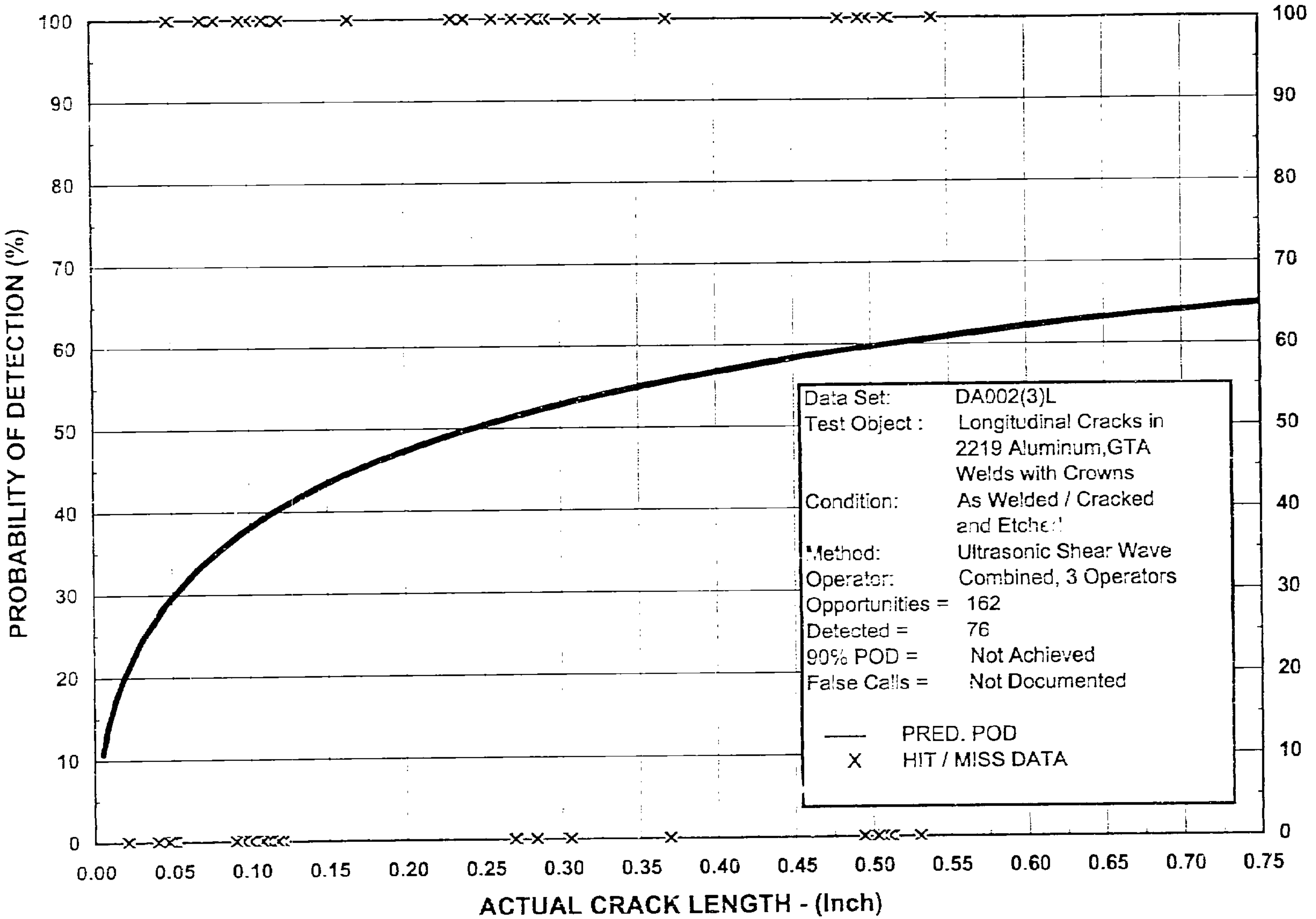
D9006(3)D
6/97 -D9006(3)D

DA000(3)L,D	**DATA SET DESCRIPTION - LONGITUDINAL WELDS WITH CROWNS**
METHOD:	Ultrasonic Shear Wave Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	Immersion - 10 MHZ, Pitch-Catch, 1/64 inch thru hole-Calibration; Gate-Threshold
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Immersion Scan - C-scan Read-out
DATA SET IDENTIFIER:	DA001(3)L,D; DA002(3)L,D; DA003(3)L,D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	192 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)L/D = 119; -02(3)L/D = 121 ; -03(3)L/D = 116 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	239 cracks (Longitudinal and Transverse) were induced in 117 panels. Approx. 90% of the weld unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	Length A= Not Achieved A= Not Achieved A= 0.349 in. (8.86 mm)
	Depth A= 0.179 in. (4.55 mm) A= Not Achieved A= 0.145 in. (3.67 mm)
	Authors Note: Variations in the ultrasonic data may be attributed primarily to variations in the alignment and warpage of the panels in a fixed immersion scanning system.
Test Specimen Descriptions	
.n AB000(3)L, Page 2.	



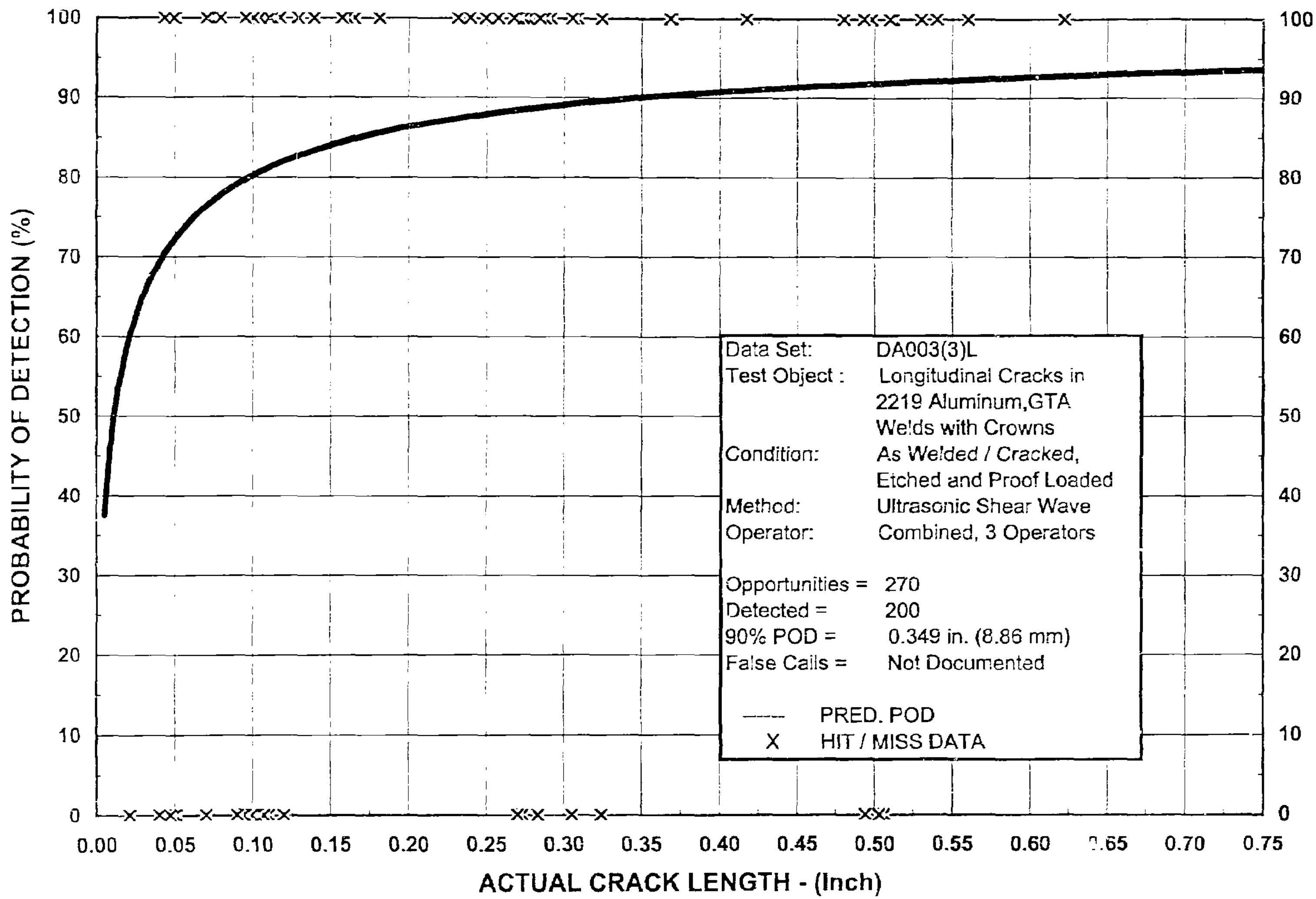
DA001(3)L
6/97 -DA001(3)L

Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



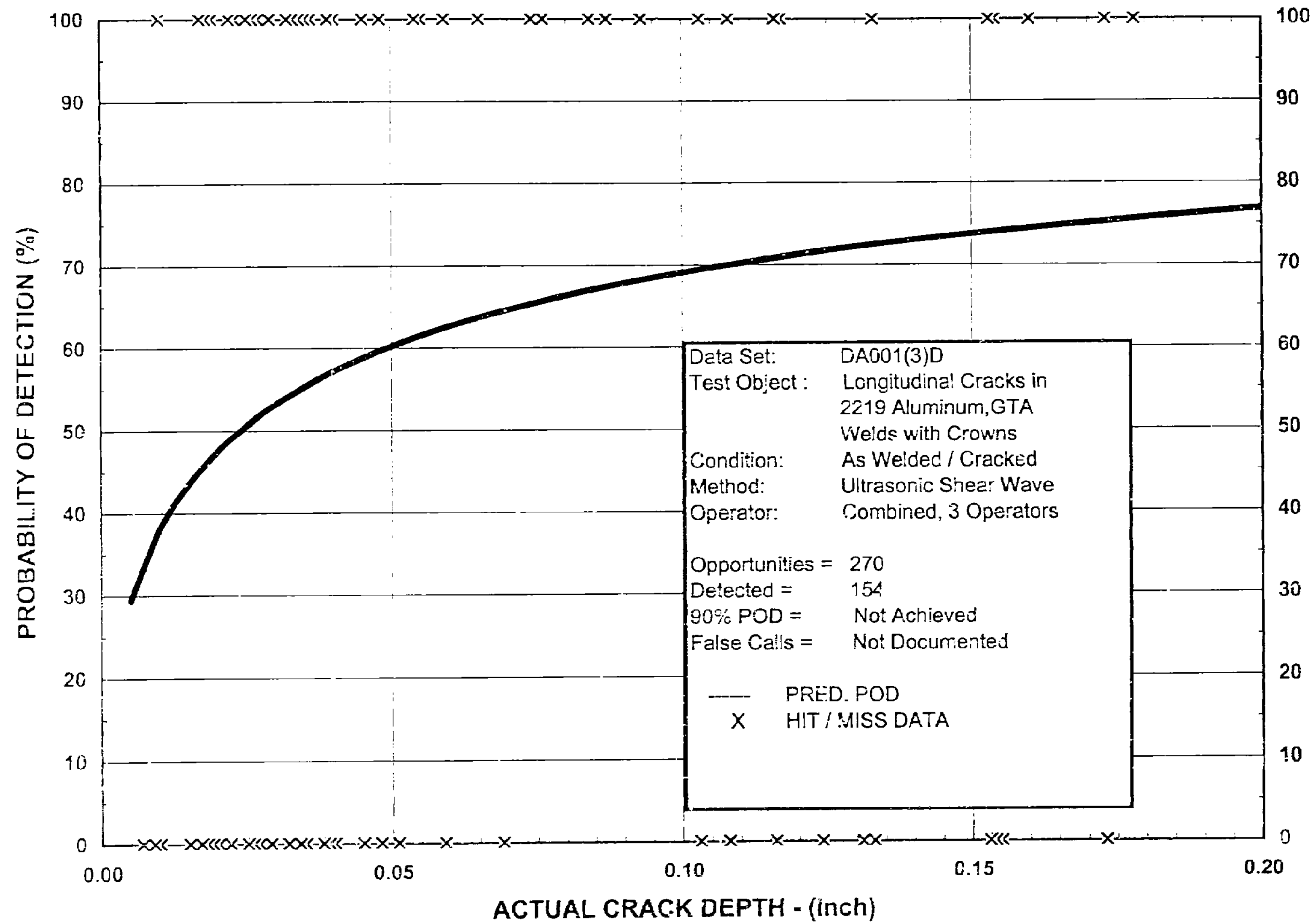
DA002(3)L
6/97 -DA002(3)L

Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched



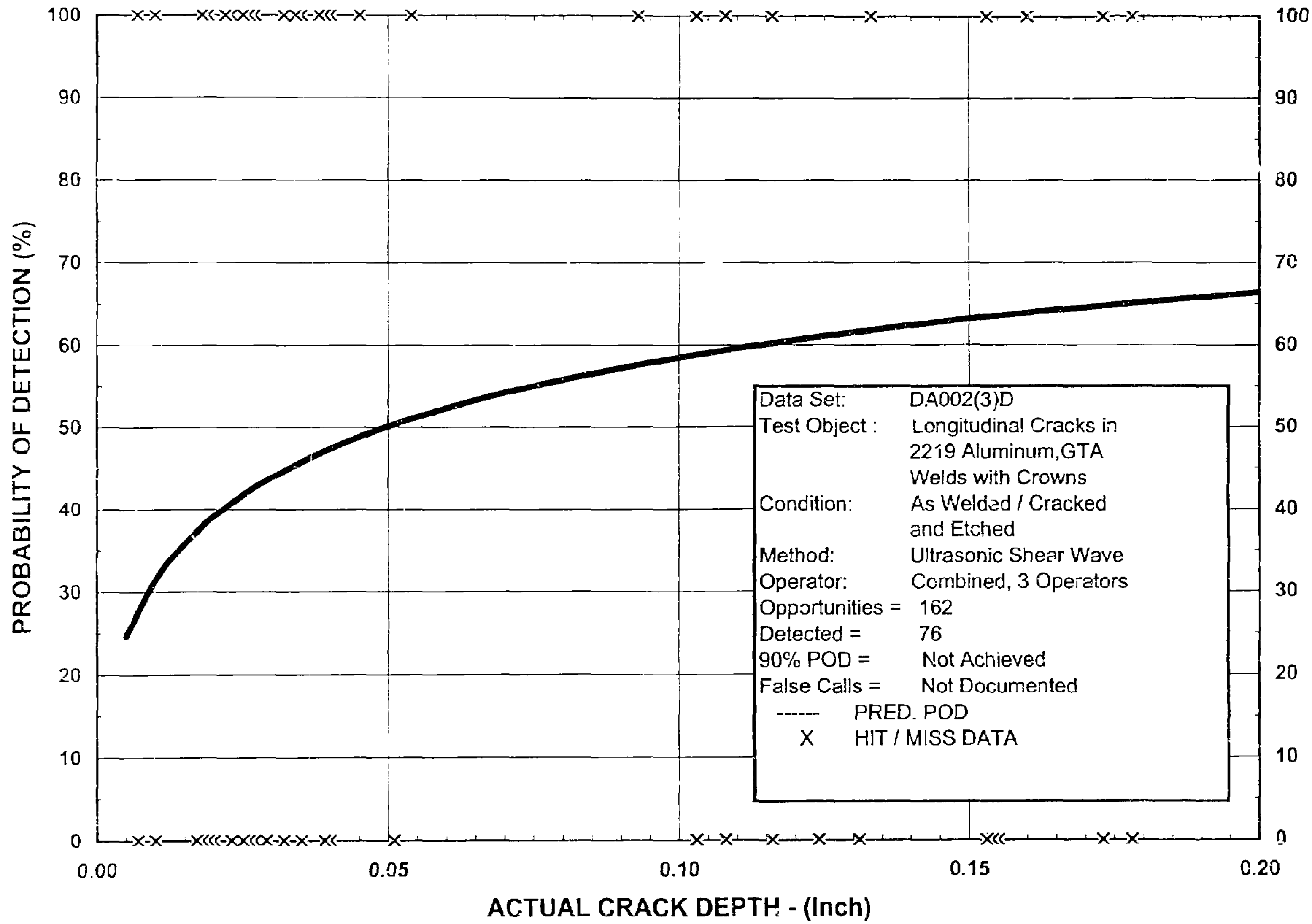
Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds
As Cracked, Scarfed, Etched and Proof Loaded

DA003(3)L
6/97 -DA003(3)L



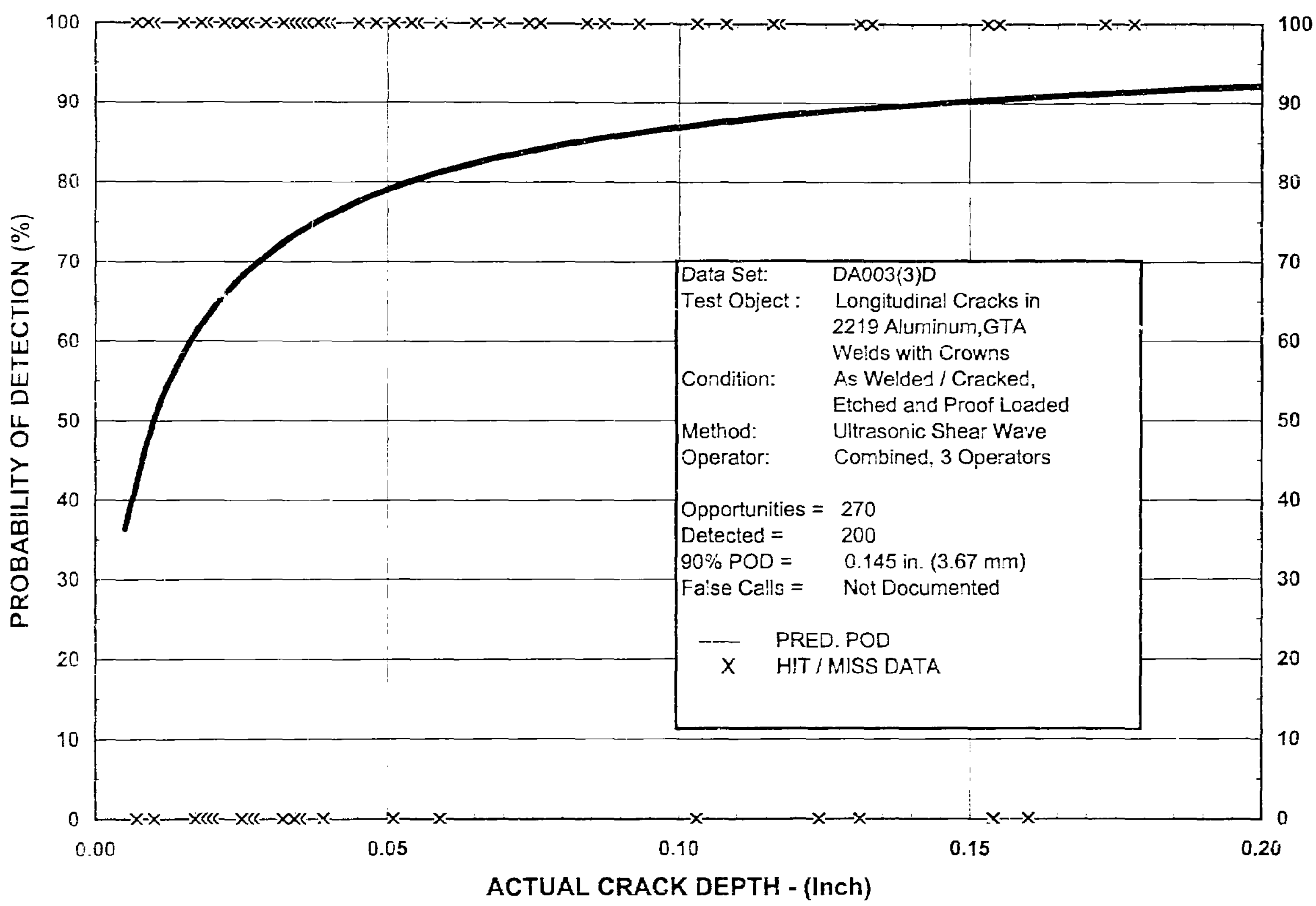
DA001(3)D
6/97 -DA001(3)D

Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



DA002(3)D
6/97 -DA002(3)D

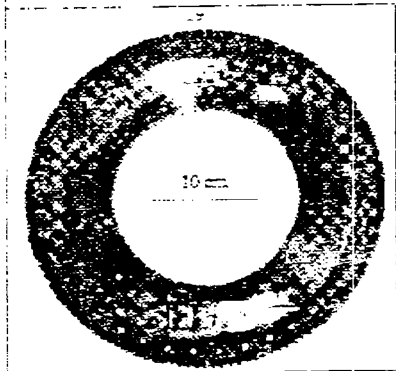
Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched

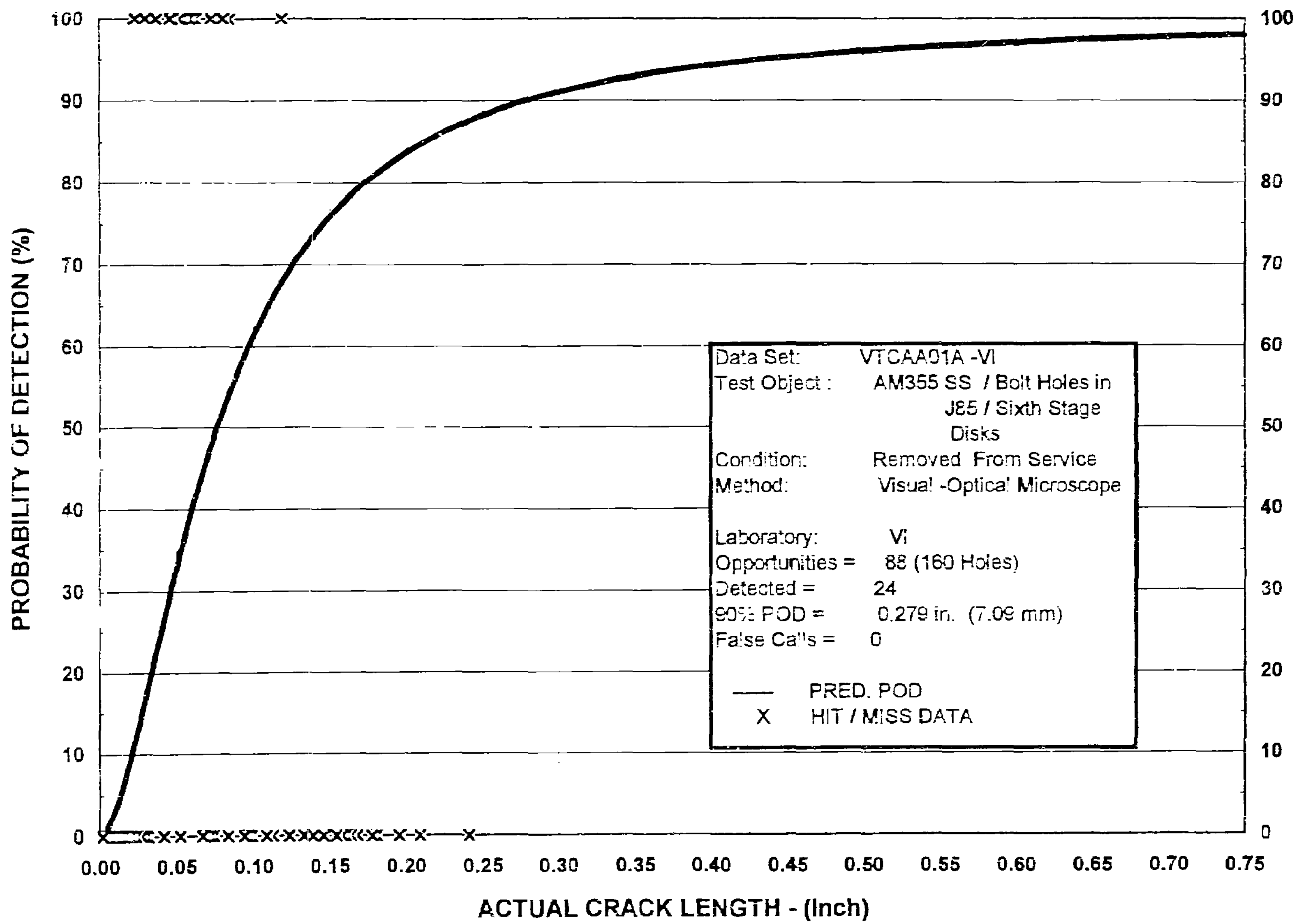


Ultrasonic Shear Wave - 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds
As Cracked, Scarfed, Etched and Proof Loaded

DA003(3)D
6/97 -DA003(3)D

VT-02(4)	DATA SET DESCRIPTION
METHOD:	Visual Inspection
TEST OBJECT TYPE:	Bolt holes in J85 / sixth stage compressor disks: 0.188" (4.8 mm) diameter
NDE PROCEDURE:	Visual Inspection / Optical Microscopy
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	VTCAA01A -VI
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	160 holes with 88 cracks
DETECTED:	24
FALSE CALLS:	None
REFERENCE:	LTR-ST-1961 Fahr, A., D. Forsyth, M. Bullock and W. Wallace. **NDI Techniques for Damage Tolerance-Based Life Prediction of Aero-Engine Turbine Disks**. February 1994.
DATE:	1988-1994
WORK SPONSOR:	AGARD - NATO, Reference Trax: JHV00
PERFORMING ORGANIZATION:	Institute for Aerospace Research, National Research Council Canada
NOTES:	This program was performed on behalf of the Structures and Materials Panel of AGARD and with the generous financial support provided by AGARD under the R&D Cooperation Program. This financial support allowed research staff of the four participating nation
	This financial support allowed research staff of the four participating nations to make short working visits to the laboratories of other countries.
	90% POD - 0.279 in. (7.09 mm)

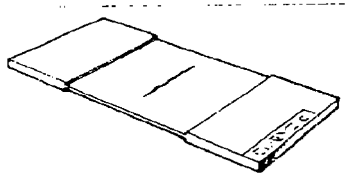




VT - 02 (4) VISUAL INSPECTION - OPTICAL MICROSCOPY
6/95

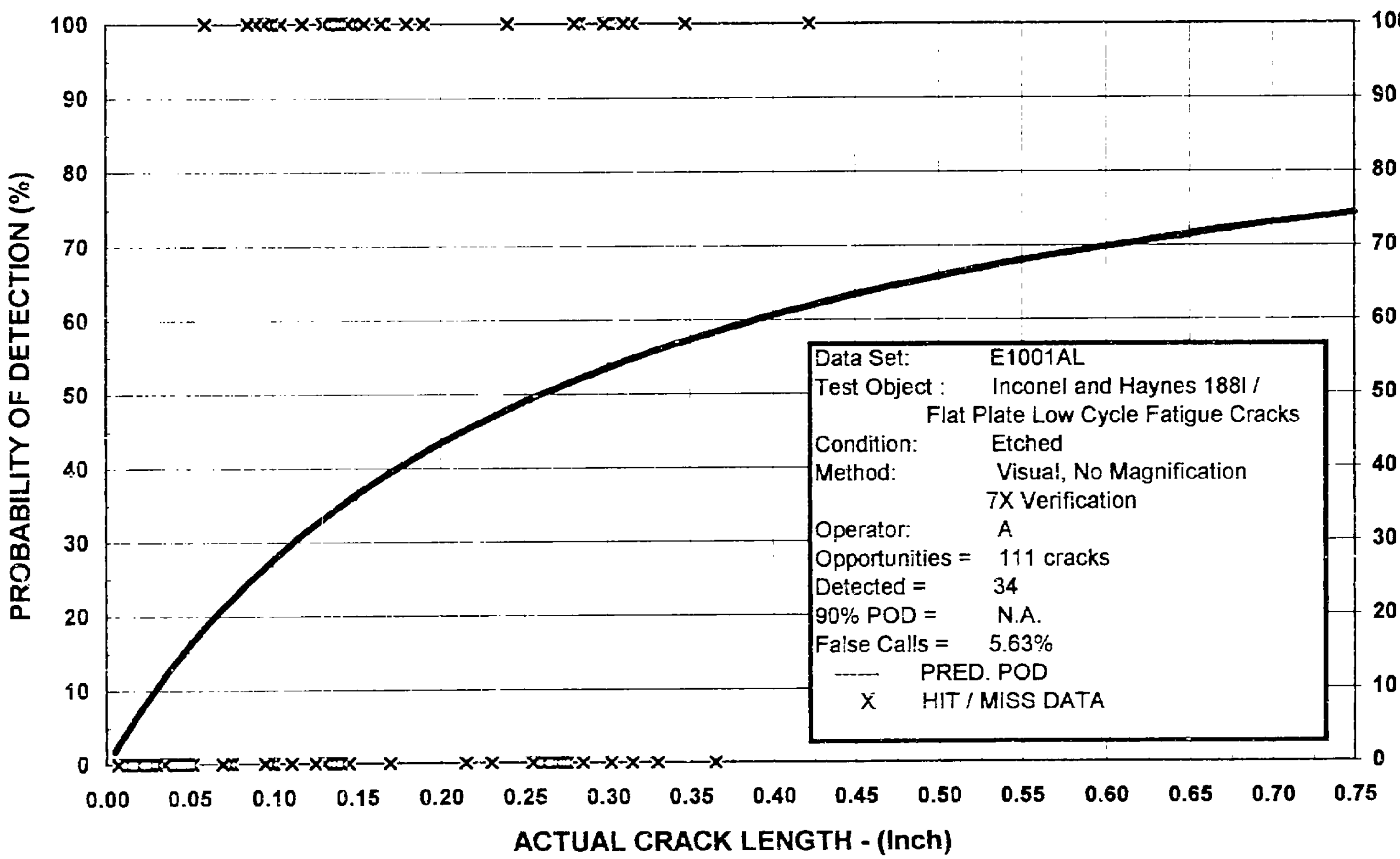
VTCAA01A-VI
GAS TURBINE ENGINE DISKS (ORG. VI)

E1000(6)L	DATA SET DESCRIPTION
METHOD:	Visual Inspection
TEST OBJECT TYPE:	Inconel 718 and Haynes 188, Flat Panels
NDE PROCEDURE:	Visual Inspection / Unaided and Aided
ARTIFACT TYPE:	Low cycle induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Monitor of crack growth procedures and fracture of representative specimens
MATERIAL:	Inconel 718 and Haynes 188, Flat Panels
TEST OBJECT THICKNESS:	0.190 inch (4.83 mm) nominal
TEST OBJECT CONDITION:	Machined, etched and cleaned
SURFACE FINISH:	As etched
APPLICATION:	Manual Inspection / Manual Recording
DATA SET IDENTIFIERS:	E1001AL and E1002AL
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	111 cracks, selected to provide a range of crack sizes
DETECTED:	E1001AL : 34 and E1002AL : 59
FALSE CALLS:	E1001AL = 5.63% and E1002AL = 1.25%
REFERENCE:	MCR-83-568 Brent K. Christner and Ward D. Rummel **NDE Detectability of Fatigue Type Cracks in High-Strength Alloys** July, 1983.
DATE:	1982-1983
WORK SPONSOR:	NASA, Marshall Space Flight Center
PERFORMING ORGANIZATION:	Martin M[illegible]etta Aerospace, Denver, Colorado
NOTES:	The data documented was collected as and independent task using a selected number of the panels described in the reference.



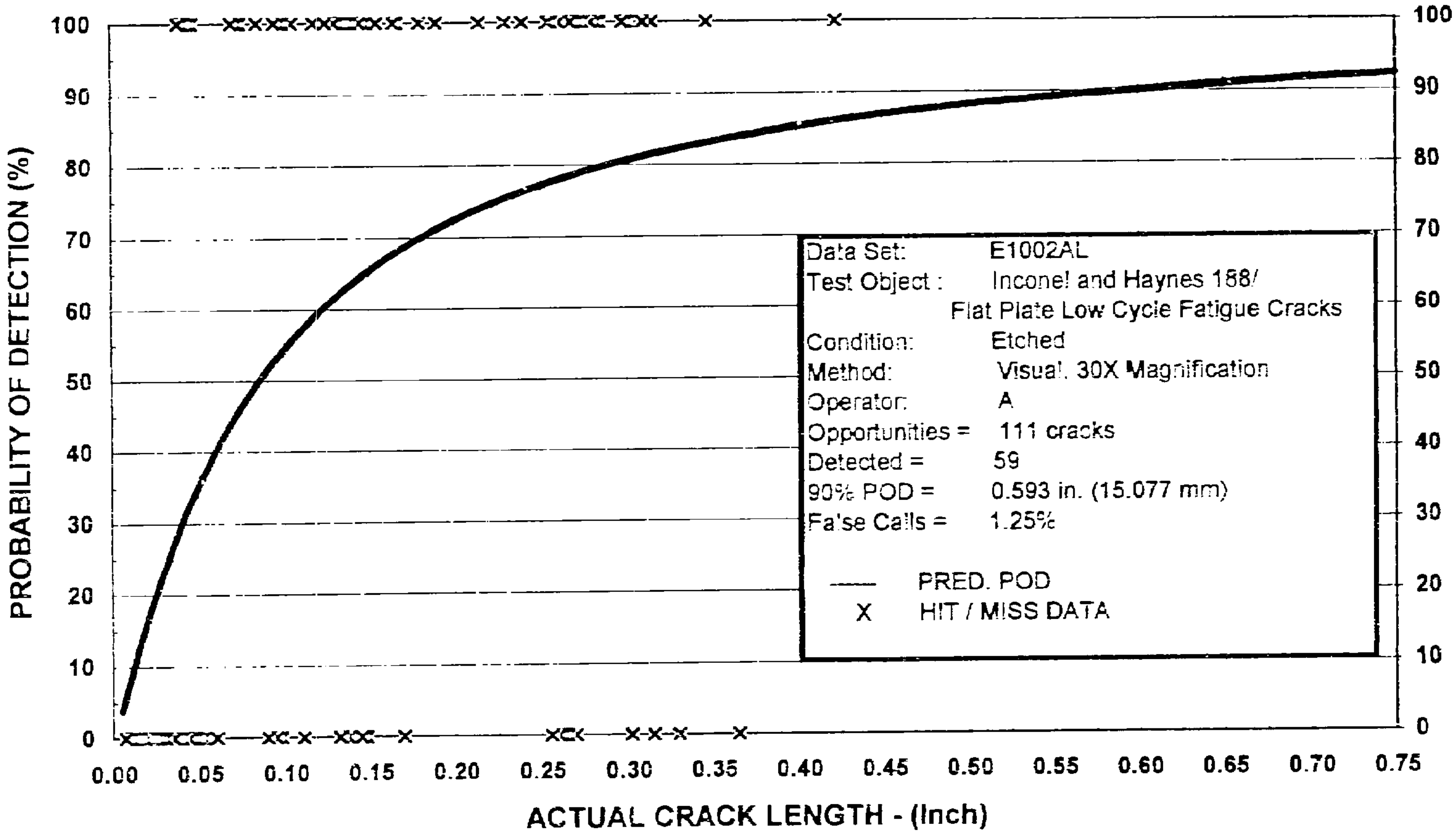
E1001AL. Unaided visual inspection with 7X magnification for verification; 90% POD not achieved

E1002AL. Visual inspection with 30X magnification; 90% POD = 0.593 in. (15.077 mm)



E1001AL
ETCHED - OPERATOR A

E1000(6) VISUAL INSPECTION OF INCONEL AND HAYNES PANELS
9/96 - E1001AL

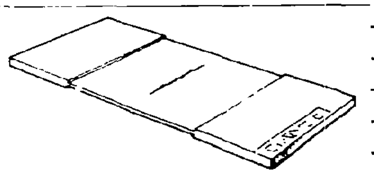


E1002AL
ETCHED - OPERATOR A

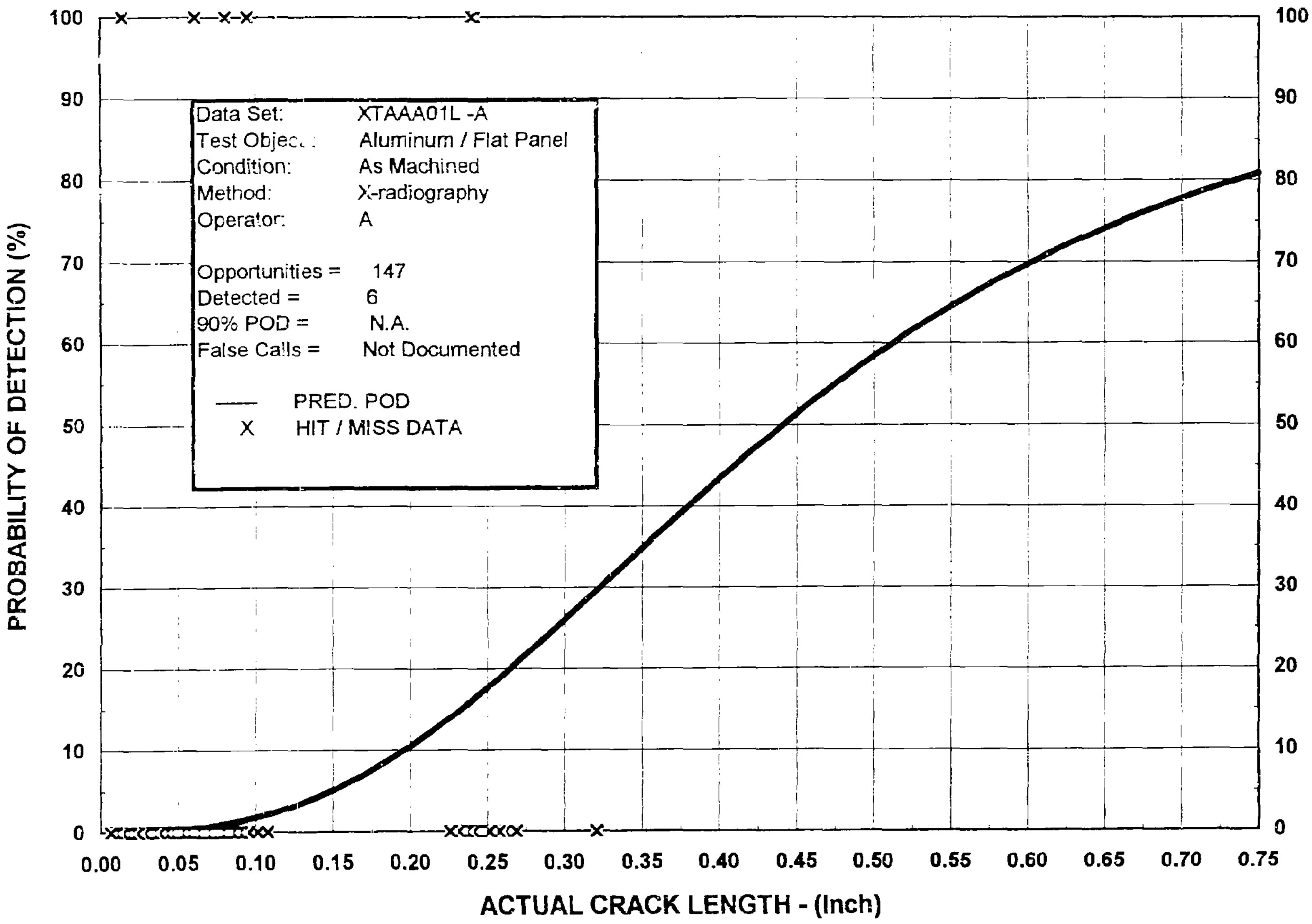
E1000(6) VISUAL INSPECTION OF INCONEL AND HAYNES PANELS

9 96 - E1002AL

XT - 01(1)A CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiography / automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 inch nominal
TEST OBJECT CONDITION:	-01 "As Machined", -02 "After Etch", -03 "After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	X-radiography / Kodak AA Film, Manual Read
DATA SET IDENTIFIER:	XTAAA01L-A,B,C; XTAAA02L-A,B,C; XTAAA03L-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	147 Cracks
DETECTED:	XTAAA01L-A= 6, B= 1, C= 2; 02L-A= 81, B= 85, C= 87; 03D-L= 100, B= 97, C= 88
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.

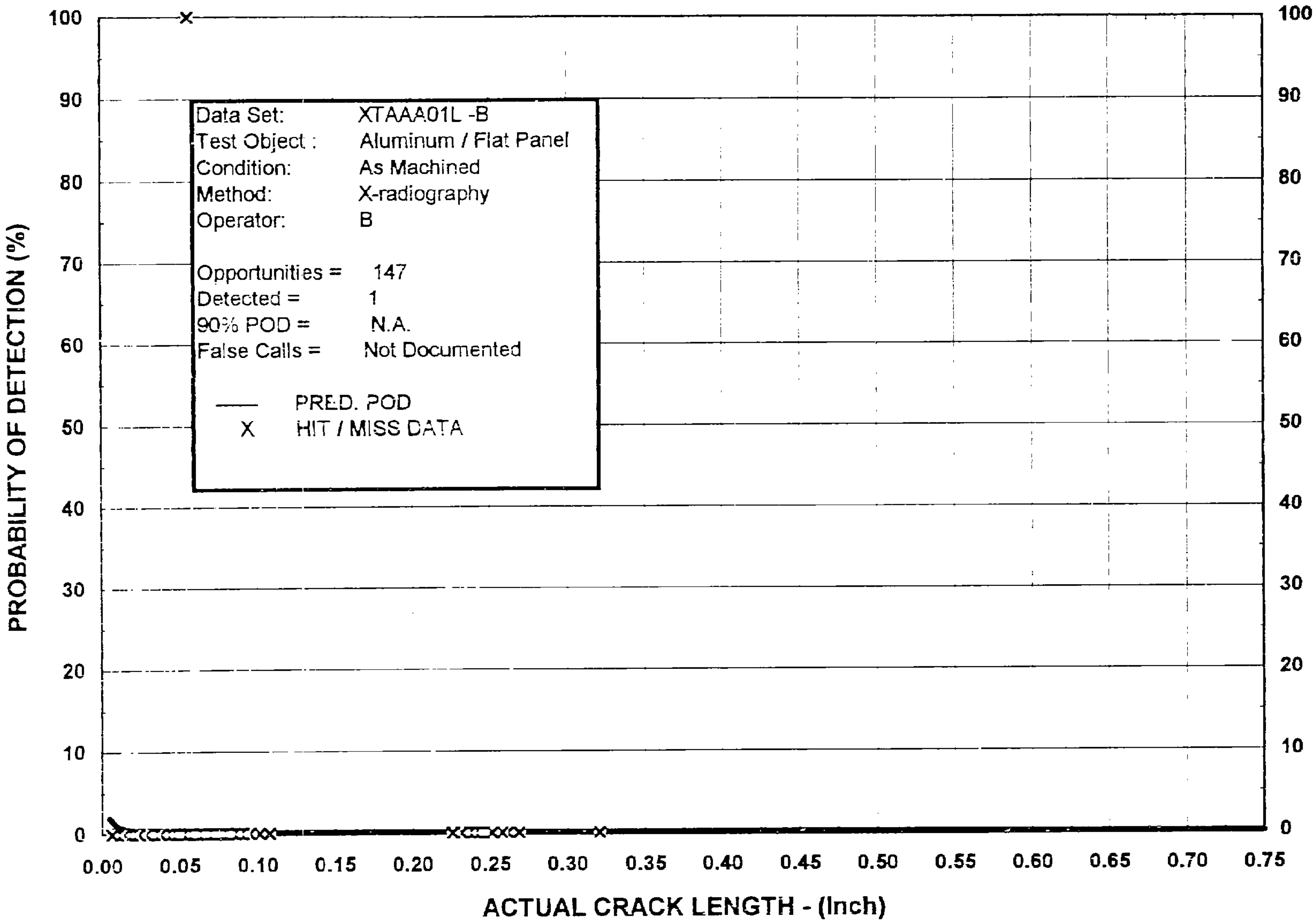


90% POD Length -	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= N.A.	A= 0.133 in.	A= 0.091 in.
	B= N.A.	B= 0.345 in.	B= 0.109 in.
	C= N.A.	C= 0.127 in.	C= 0.139 in.



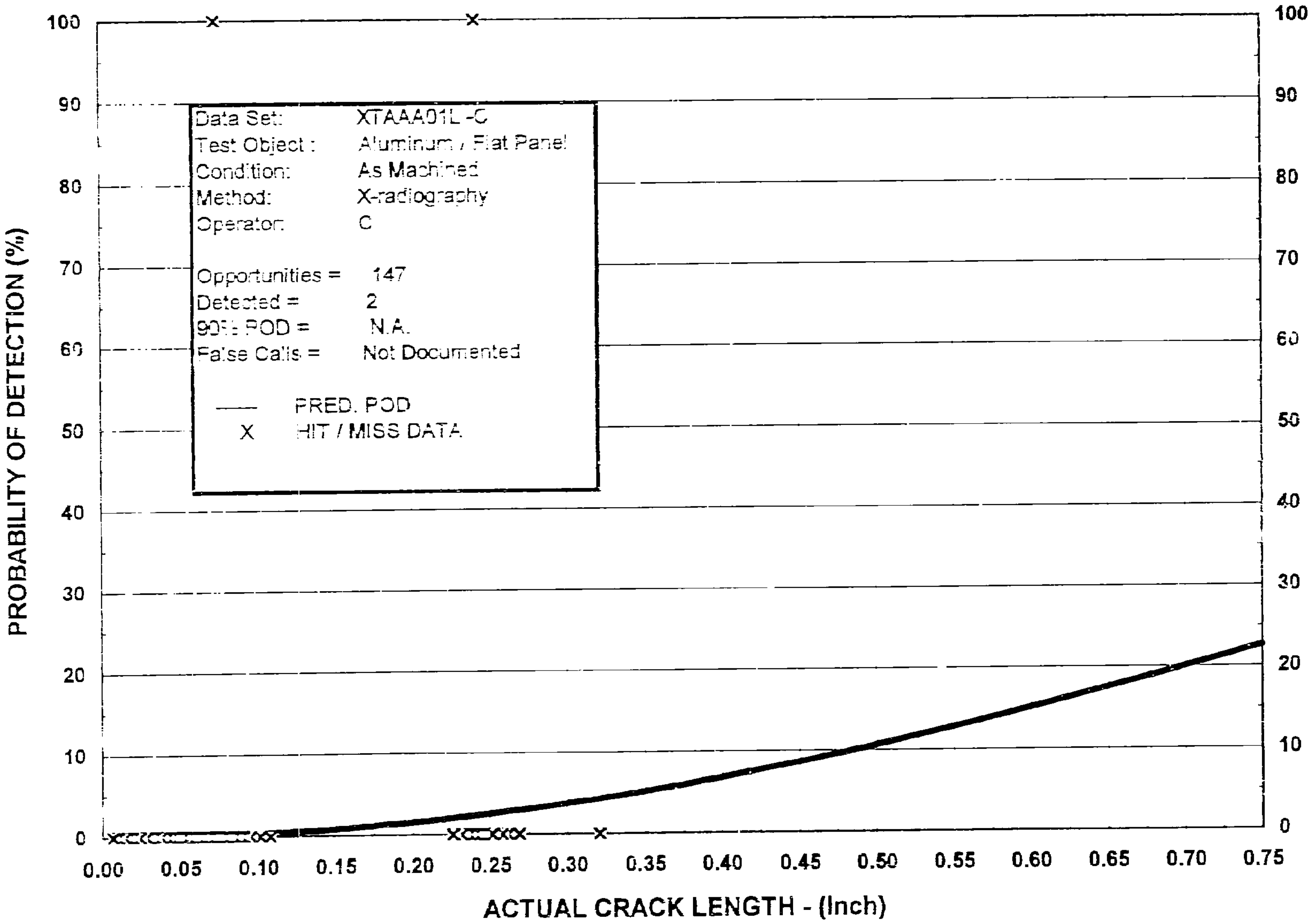
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01L-A



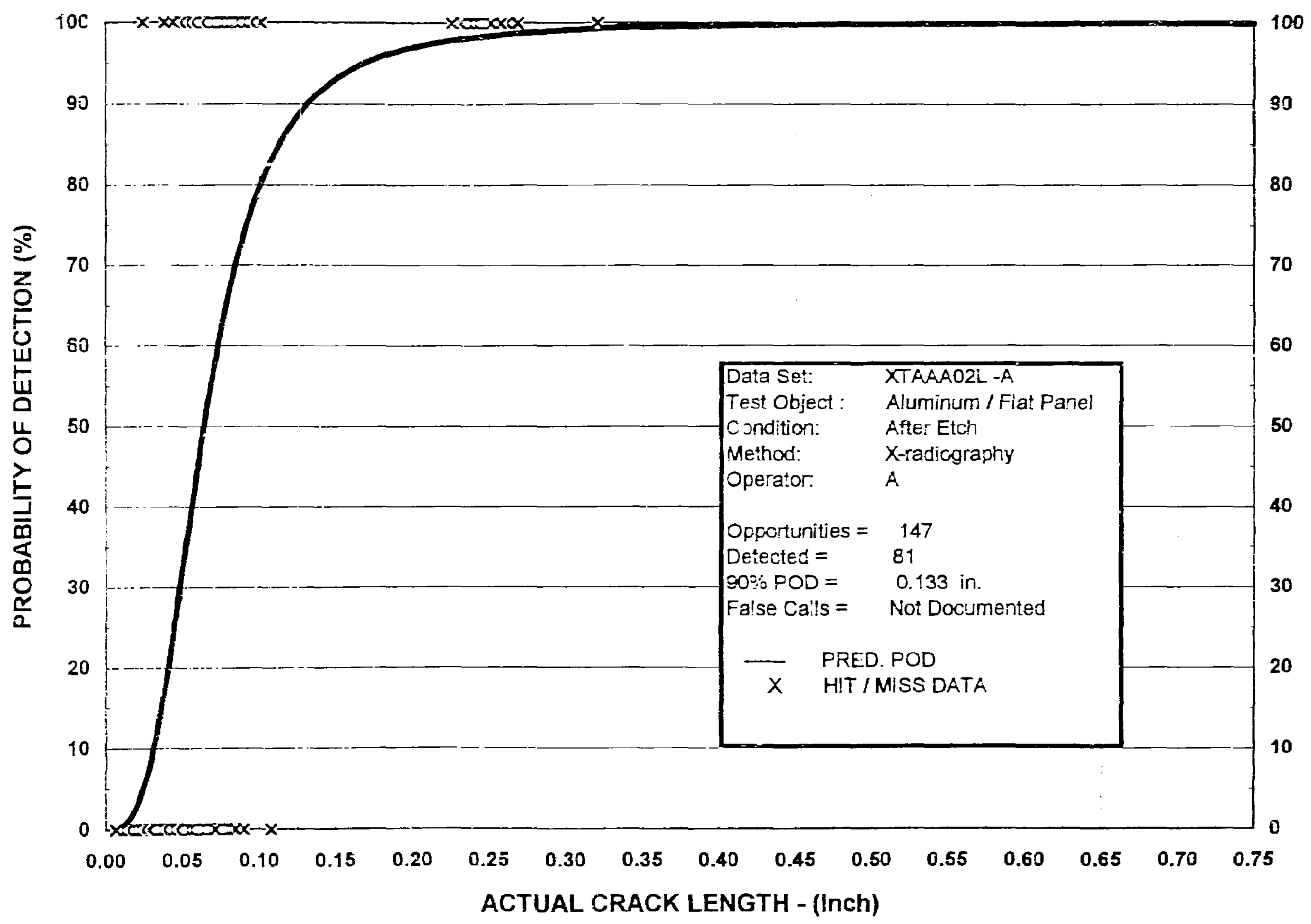
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01L-B



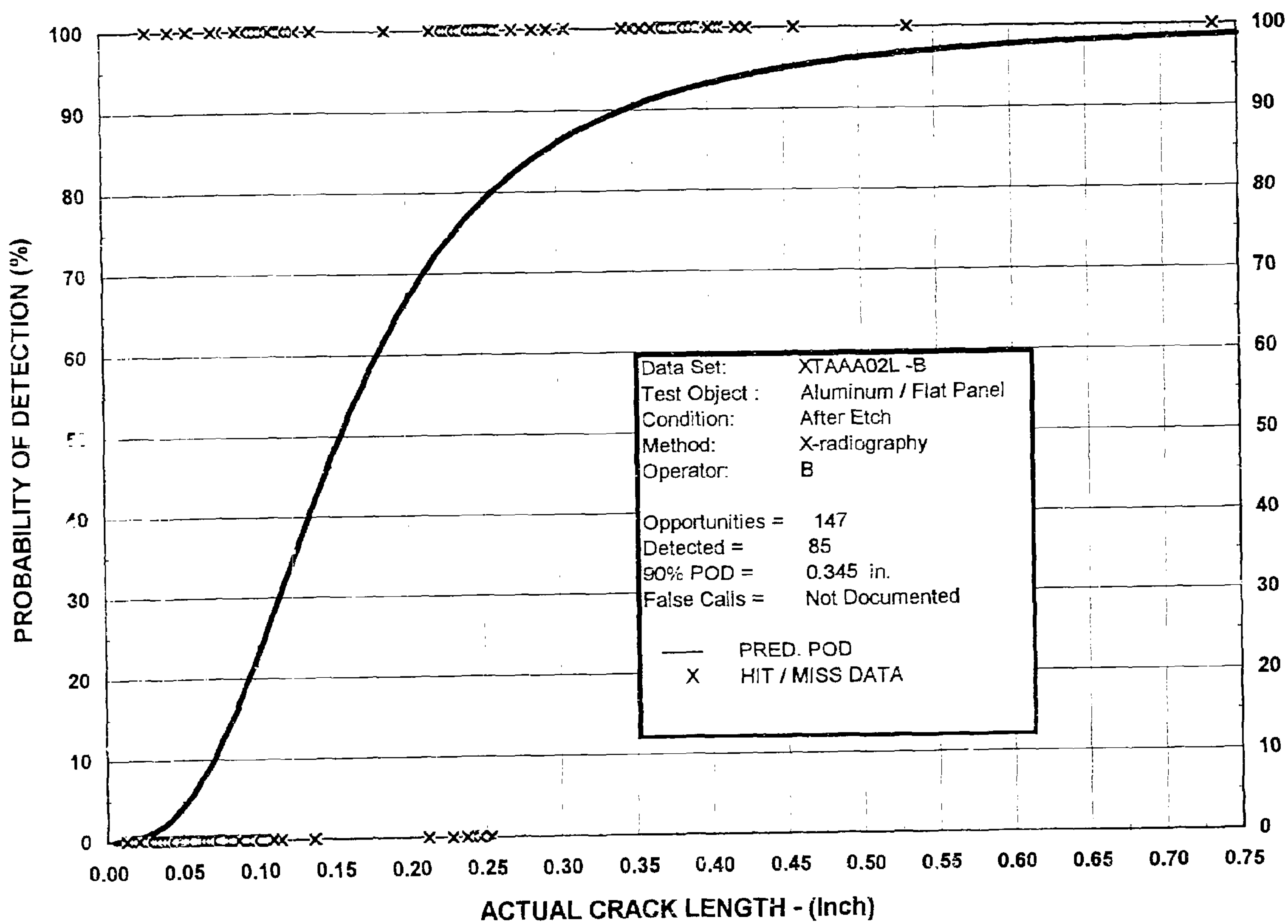
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01L-C



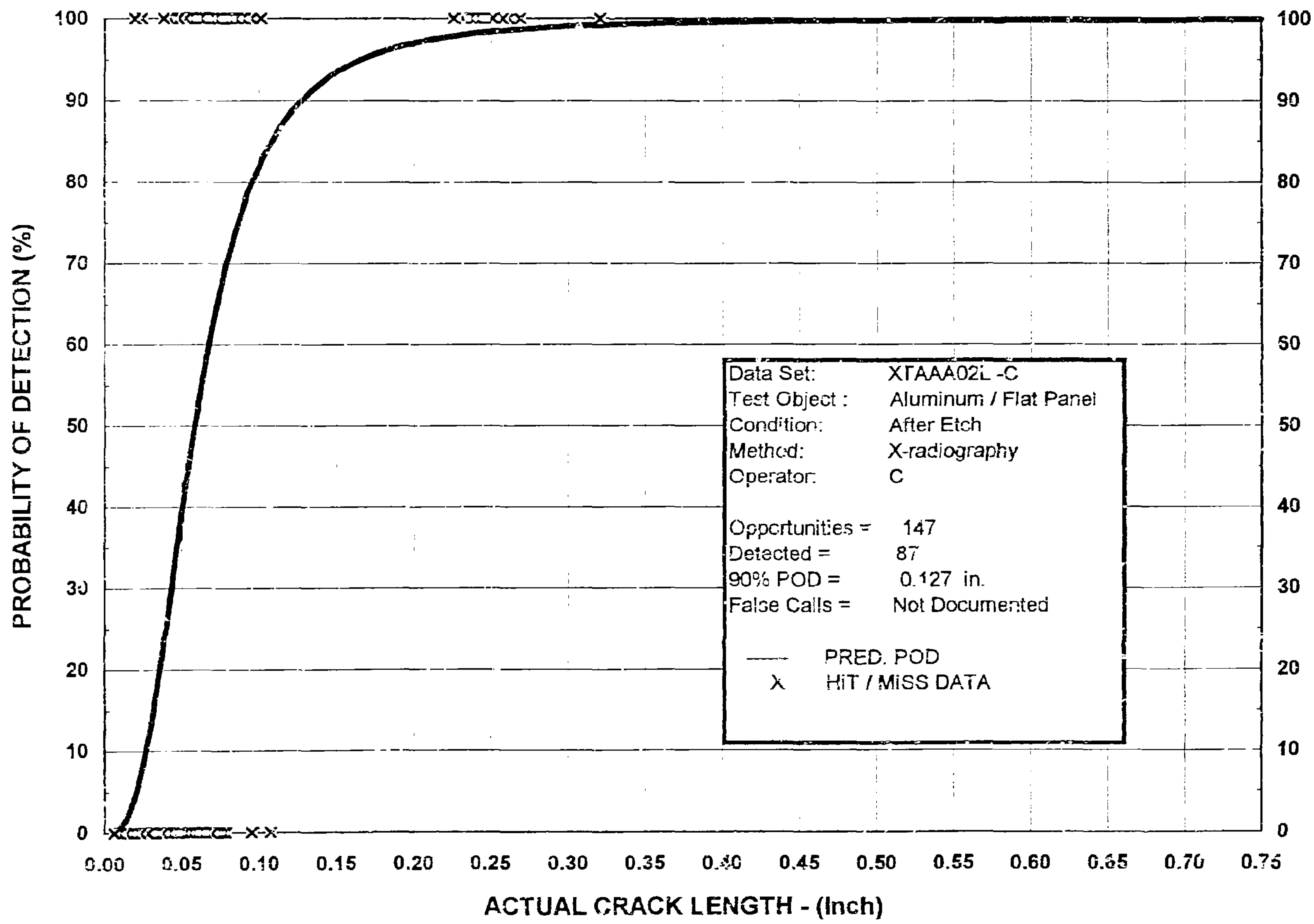
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA02L-A



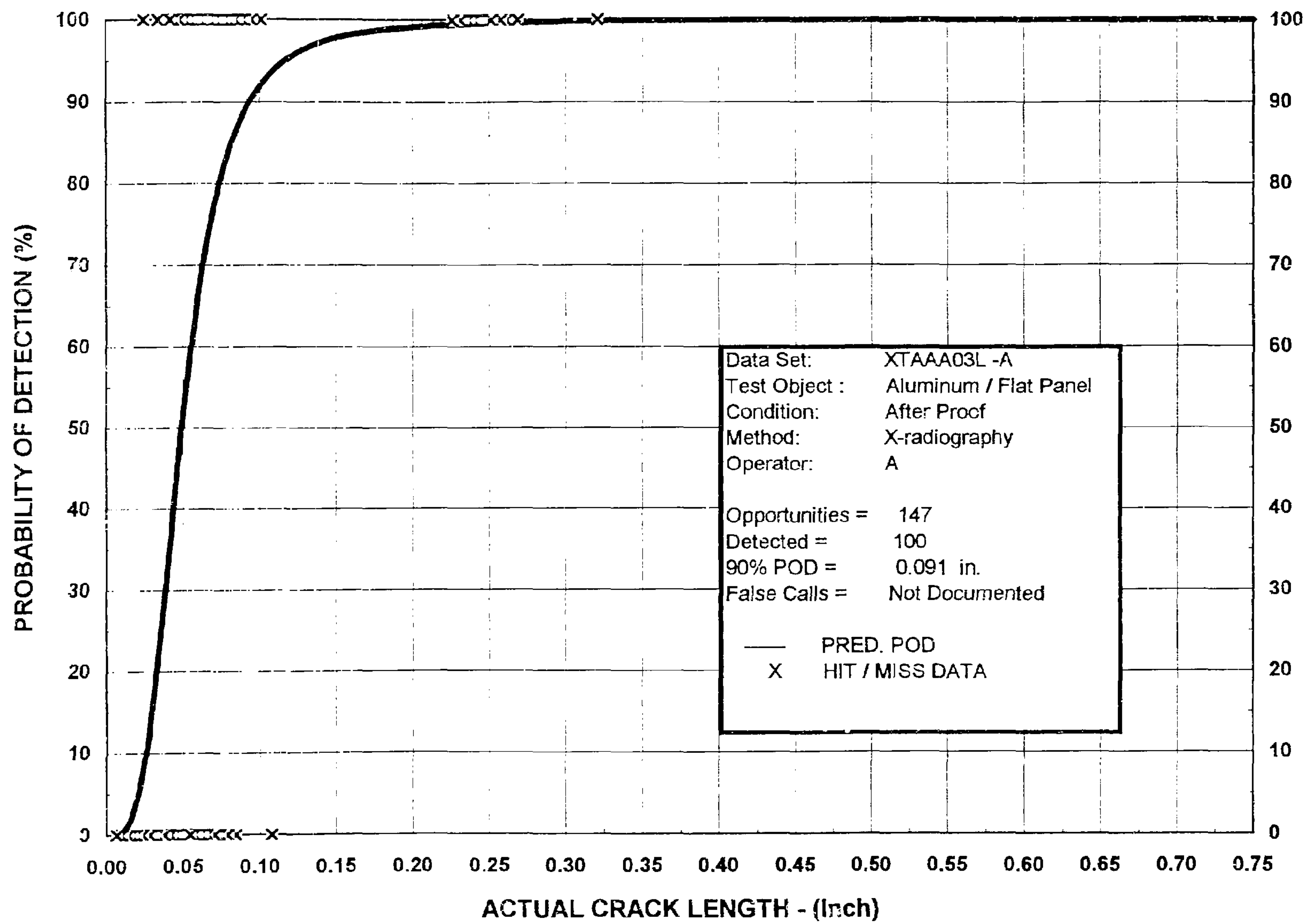
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA02L-B



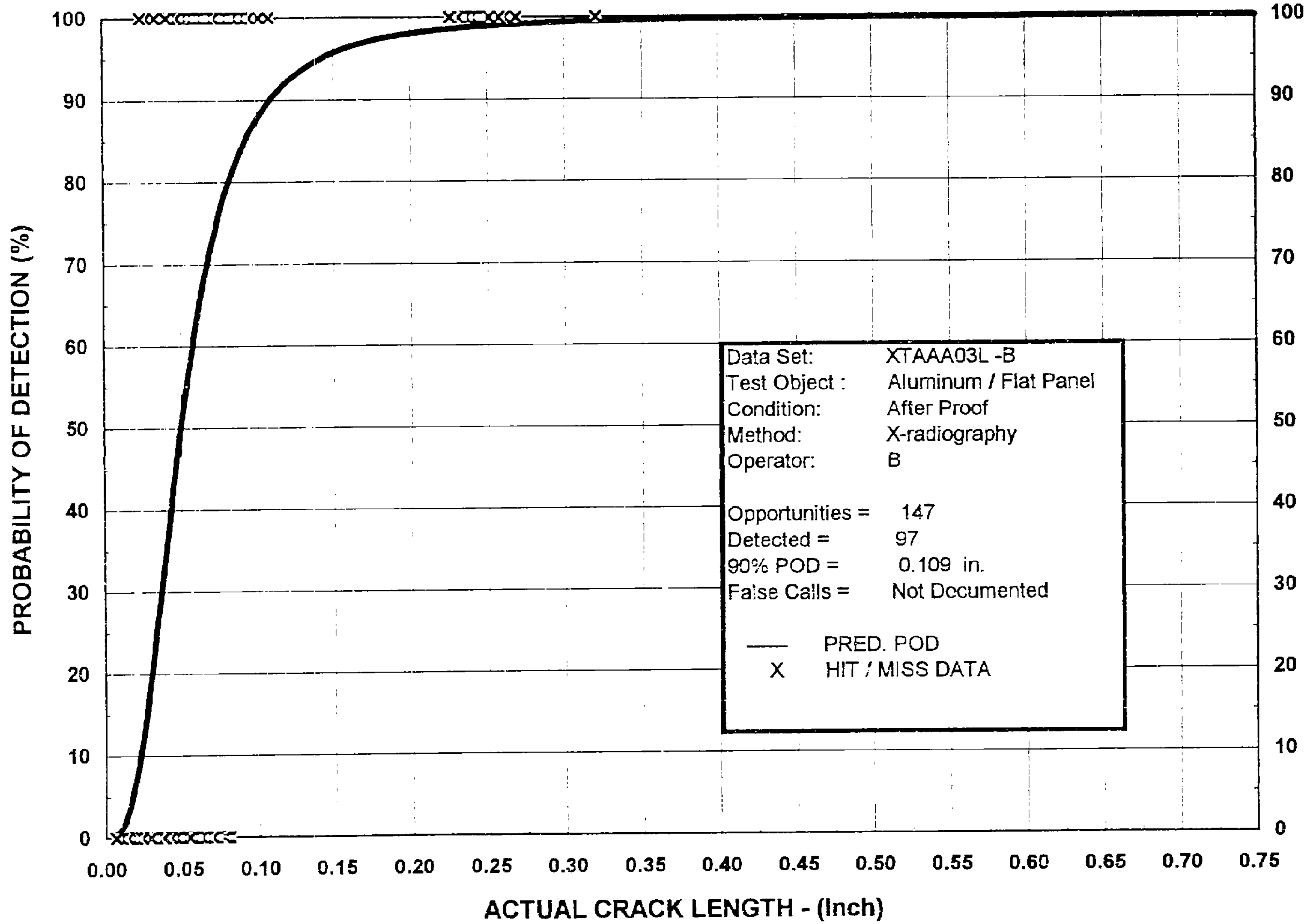
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA02L-C



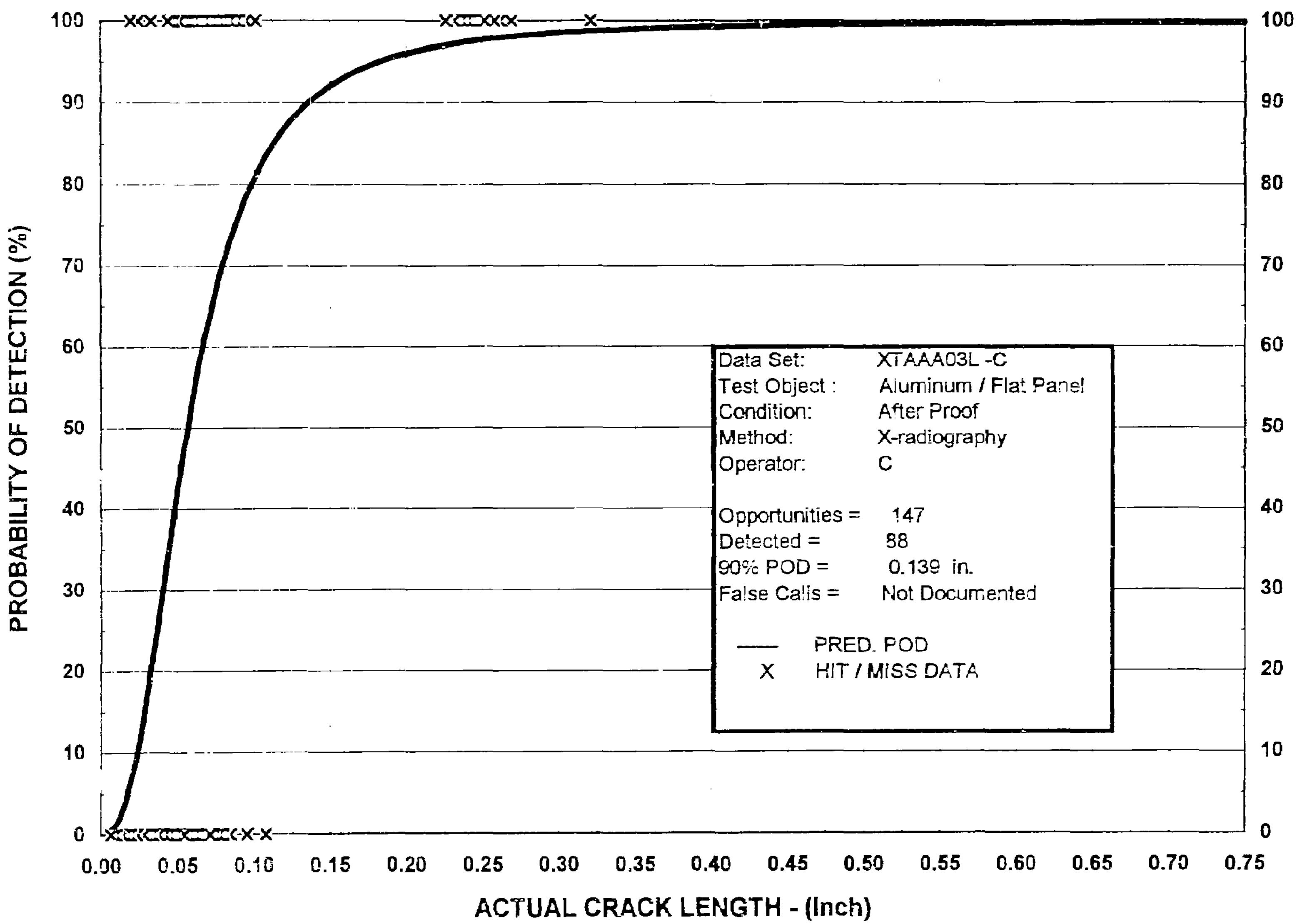
XT - 01 (1)A CRACK LENGTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA03L-A



XT - 01 (1)A CRACK LENGTH
6/95

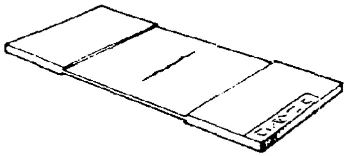
0.060 Inch Nominal Panel Thickness - XTAAA03L-B

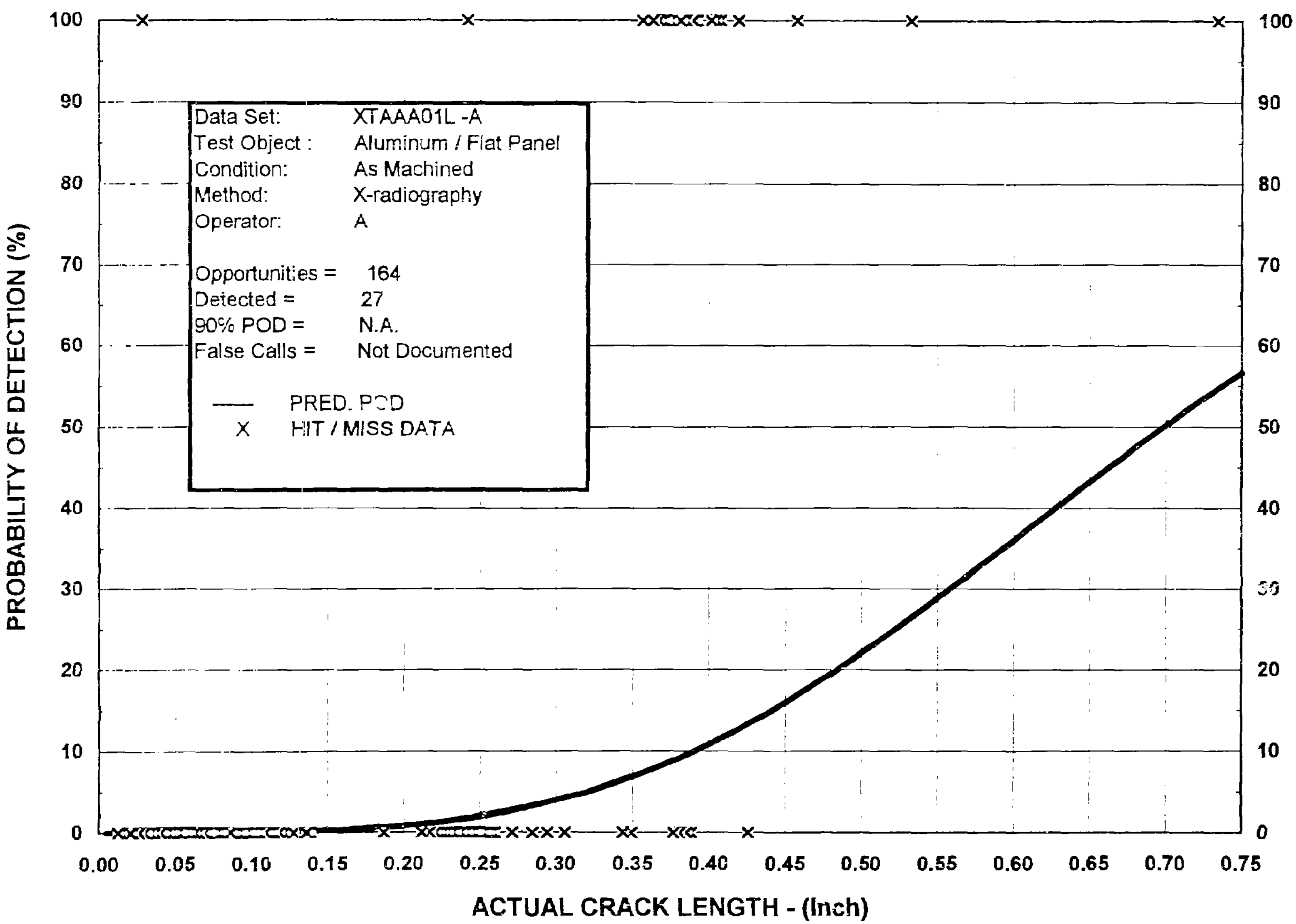


XT - 01 (1)A CRACK LENGTH

6/95

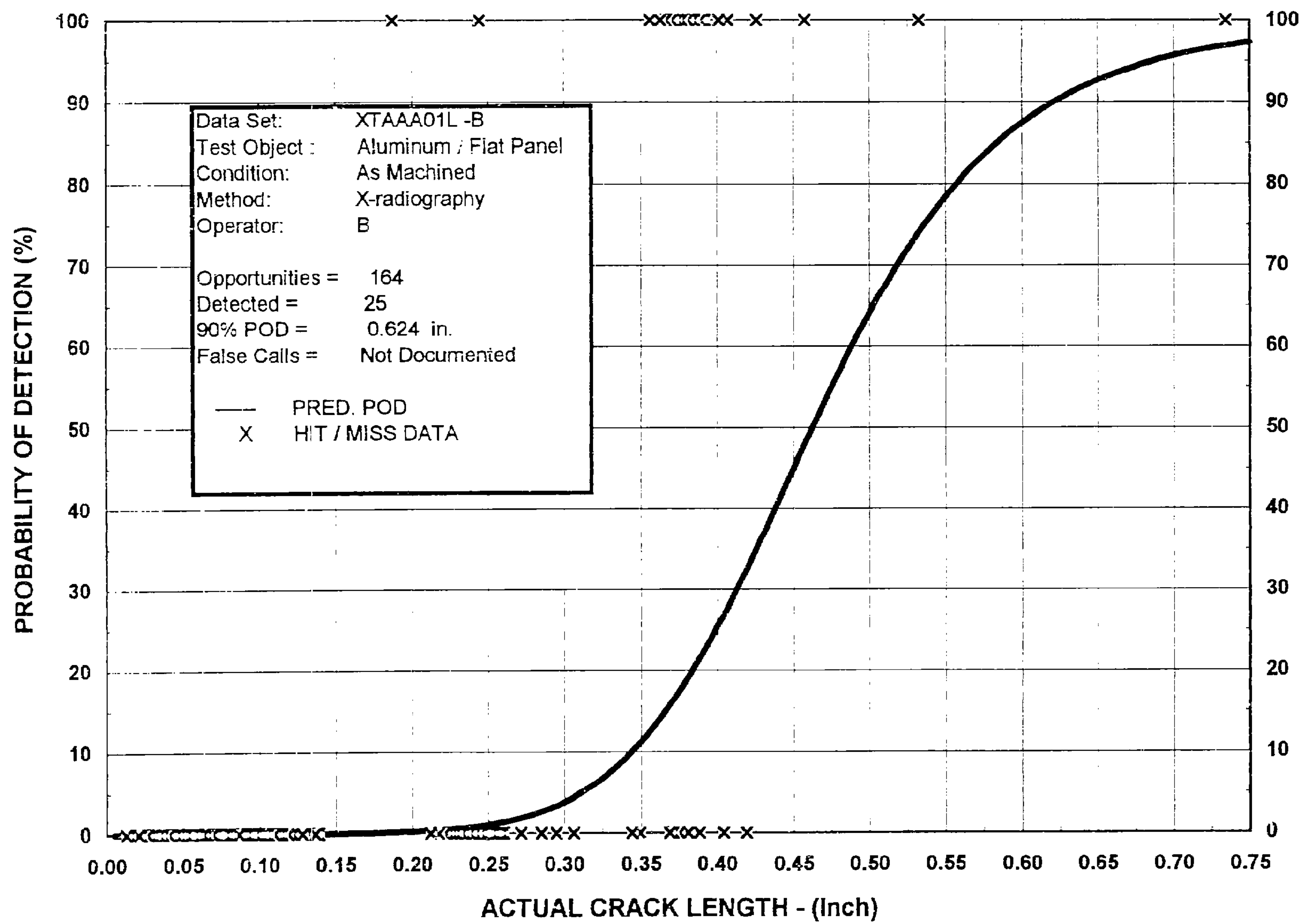
0.060 Inch Nominal Panel Thickness - XTAAA03L-C

XT - 01 (1)B CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	*Flat Plate - 3.5 inches by 16 inches, cracks on both sides*
NDE PROCEDURE:	X-radiography / automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.220 inch nominal
TEST OBJECT CONDITION:	-01."As Machined", -02."After Etch", -03."After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	X-radiography / Kodak AA Film, Manual Read
DATA SET IDENTIFIER:	XTAAA01L-A,B,C; XTAAA02L-A,B,C; XTAAA03L-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	164 Cracks / 03L 159 Cracks
DETECTED:	XTAAA01L-A= 27, B= 25, C= 32; 02L-A= 68, B= 68, C= 77; 03L-A= 85, B= 84, C= 89
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke. **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp. San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.
	90% POD Length - "AS MACHINED" "AFTER ETCH" "AFTER PROOF"
	A= N.A. A= 0.616 in. A= 0.285 in.
	B= 0.624 in. B= 0.340 in. B= 0.302 in.
	C= N.A. C= 0.601 in. C= 0.296 in.



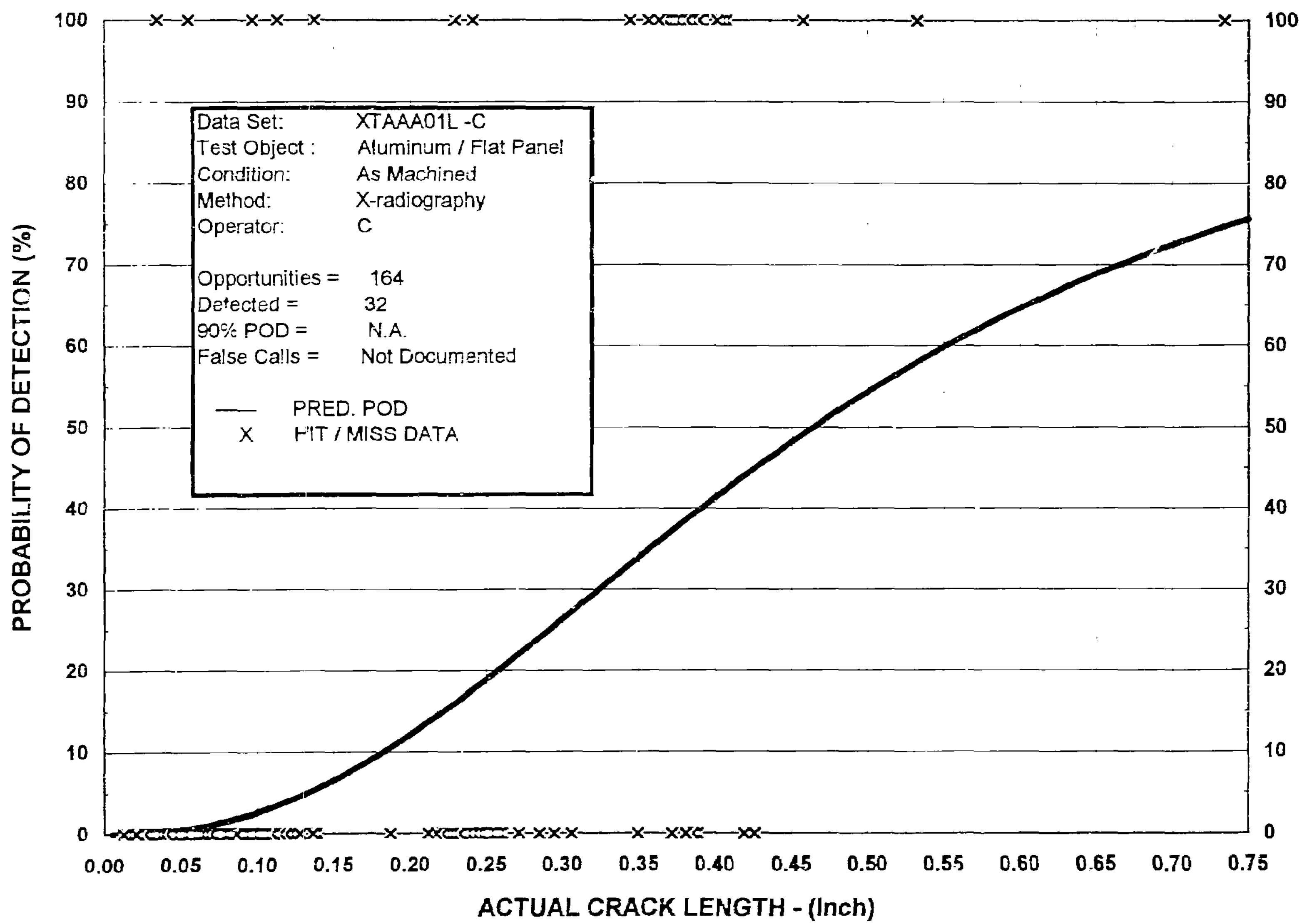
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA01L-A



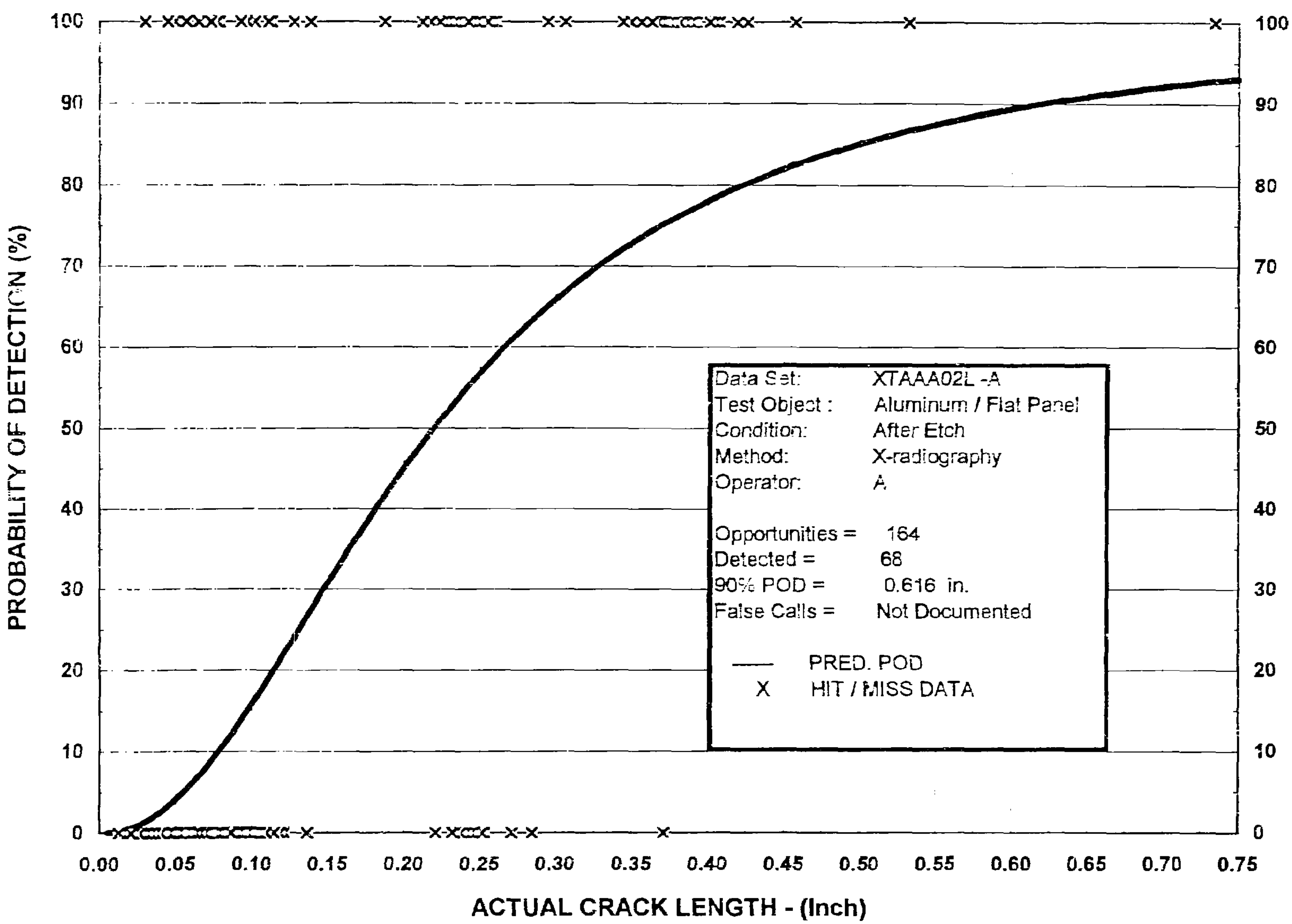
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA01L-B



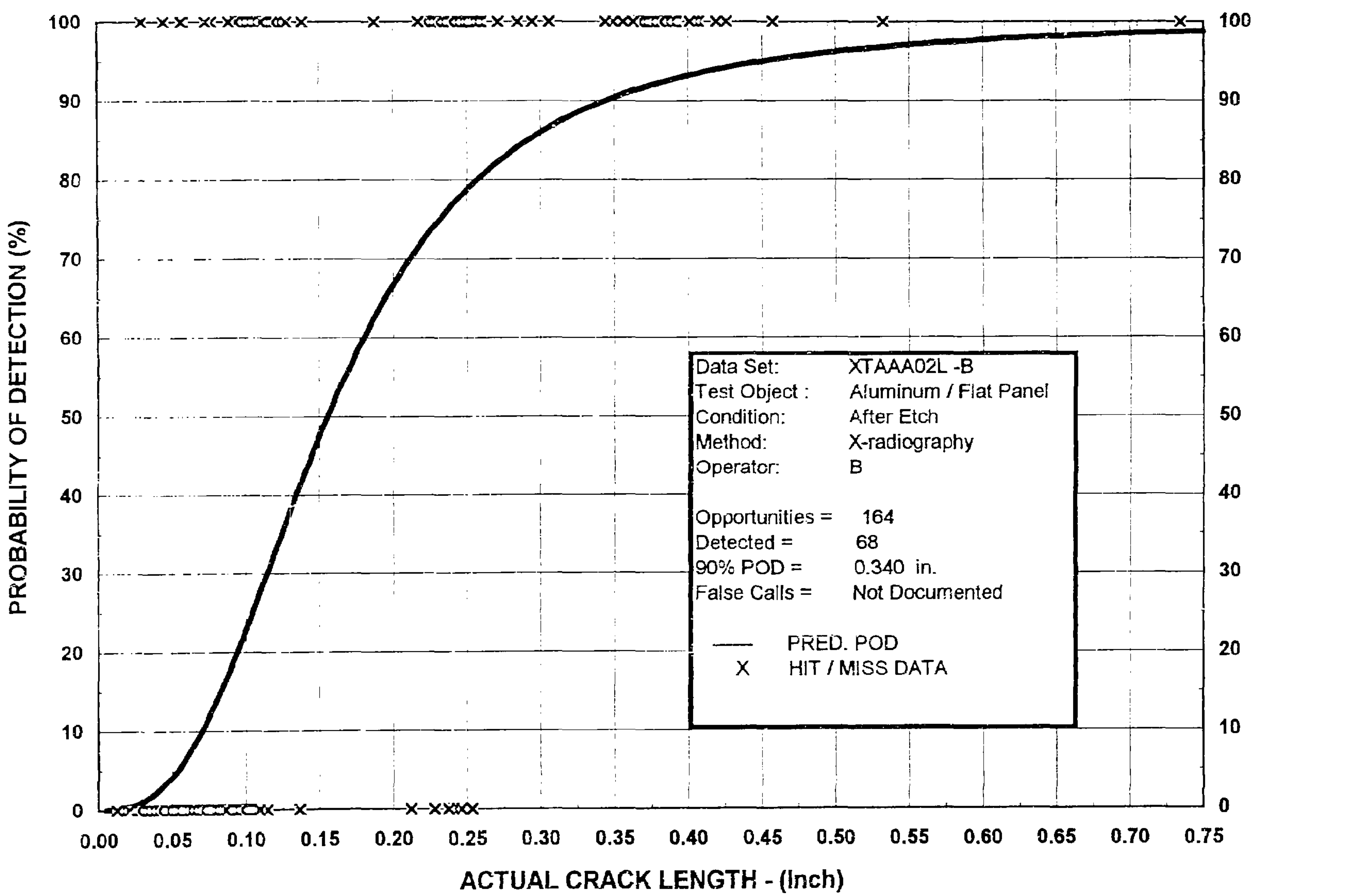
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA01L-C



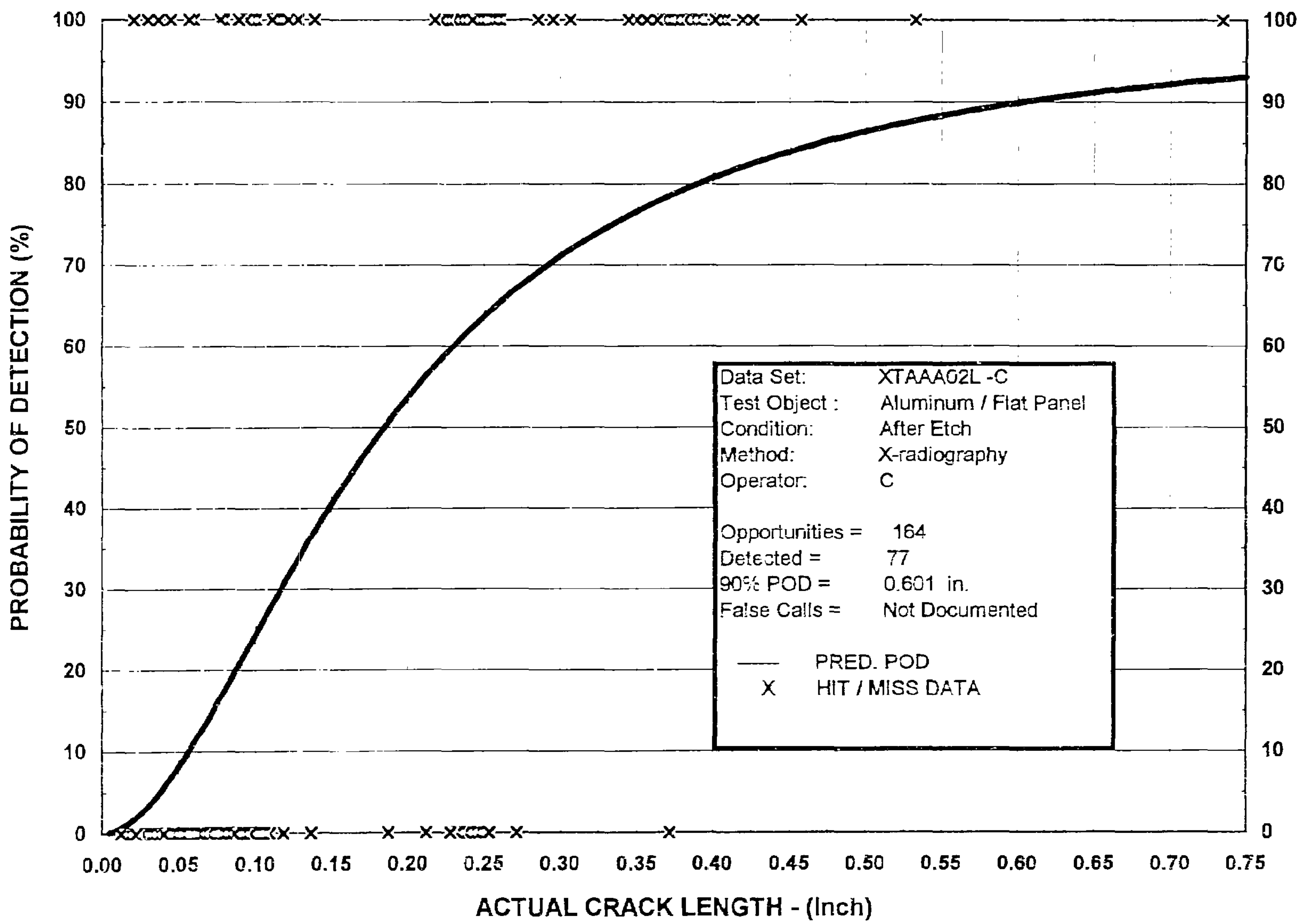
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA02L-A



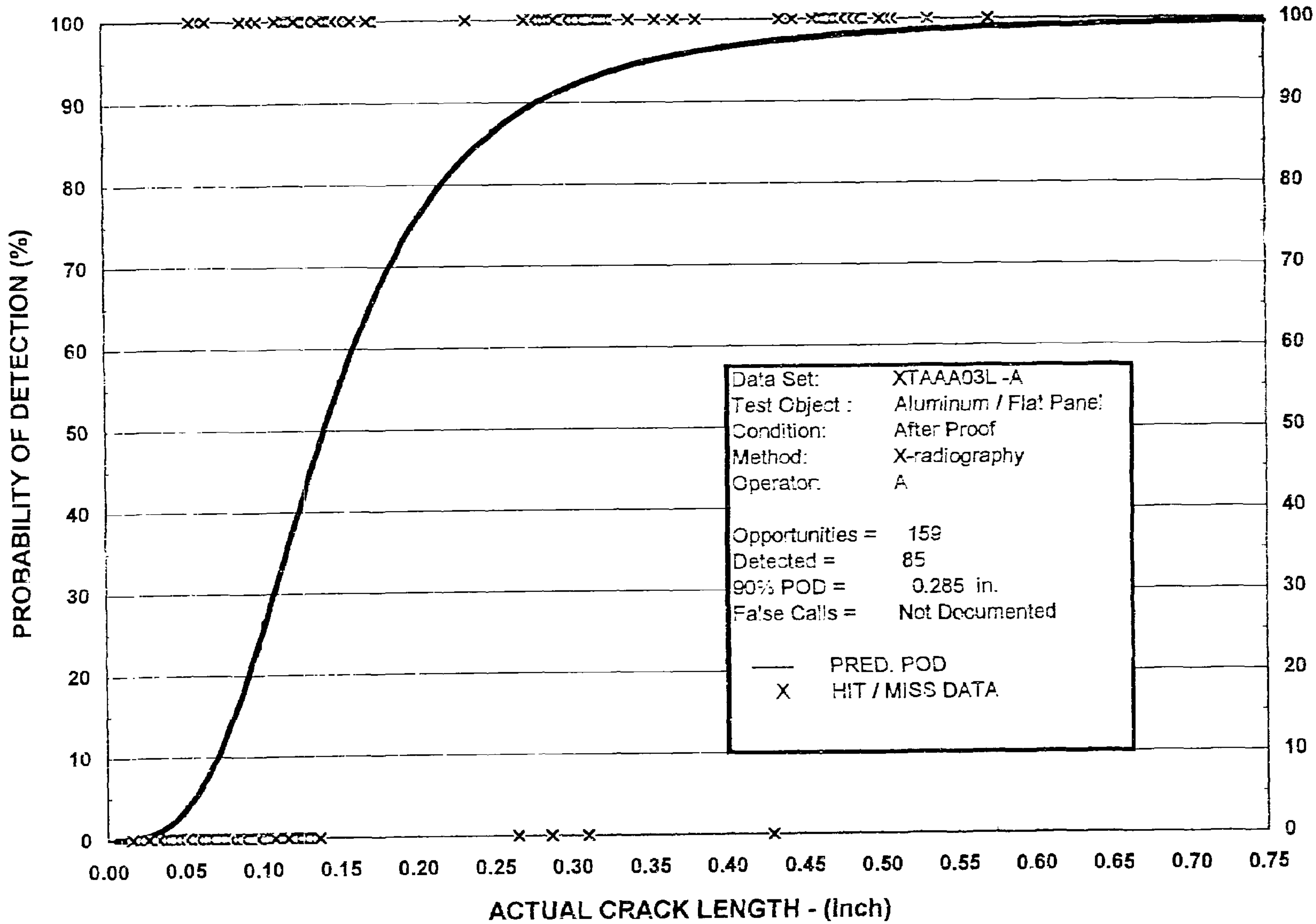
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA02L-B



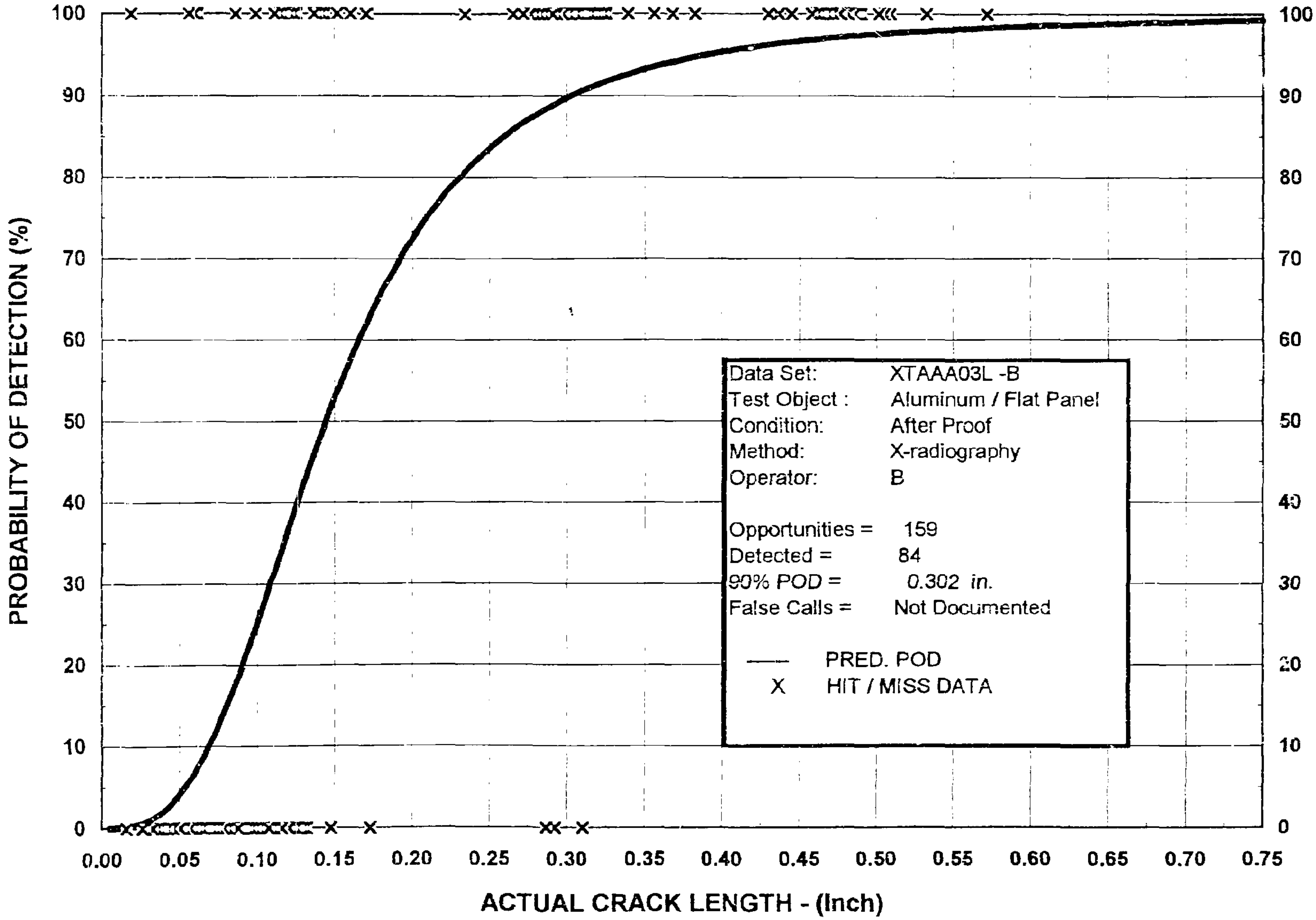
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA02L-C



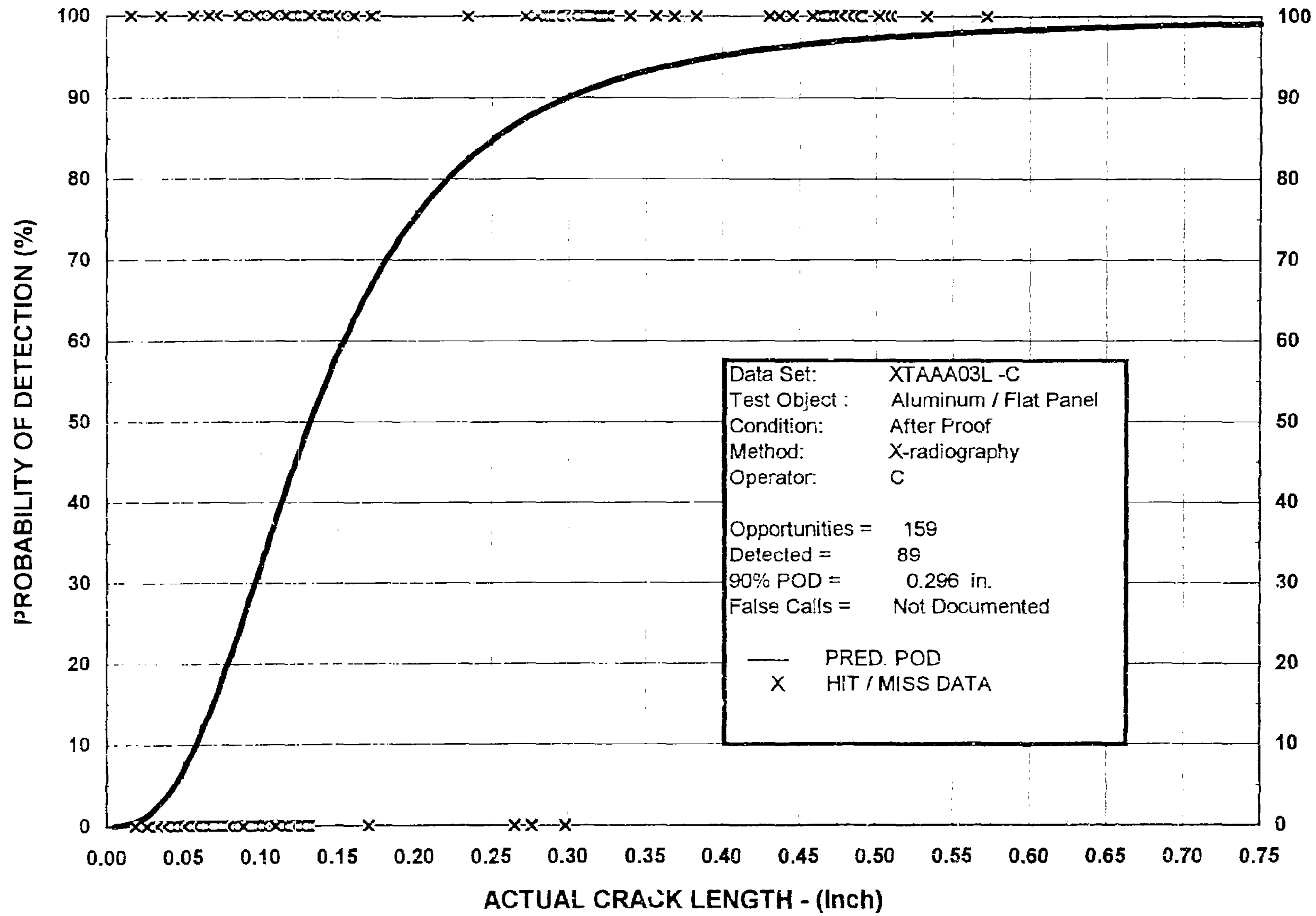
XT - 01 (1)B CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA03L-A



XT - 01 (1)B CRACK LENGTH
6/95

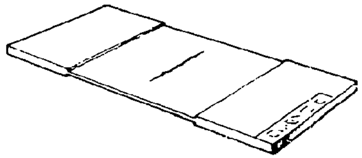
0.220 Inch Nominal Panel Thickness - XTAAA03L-B

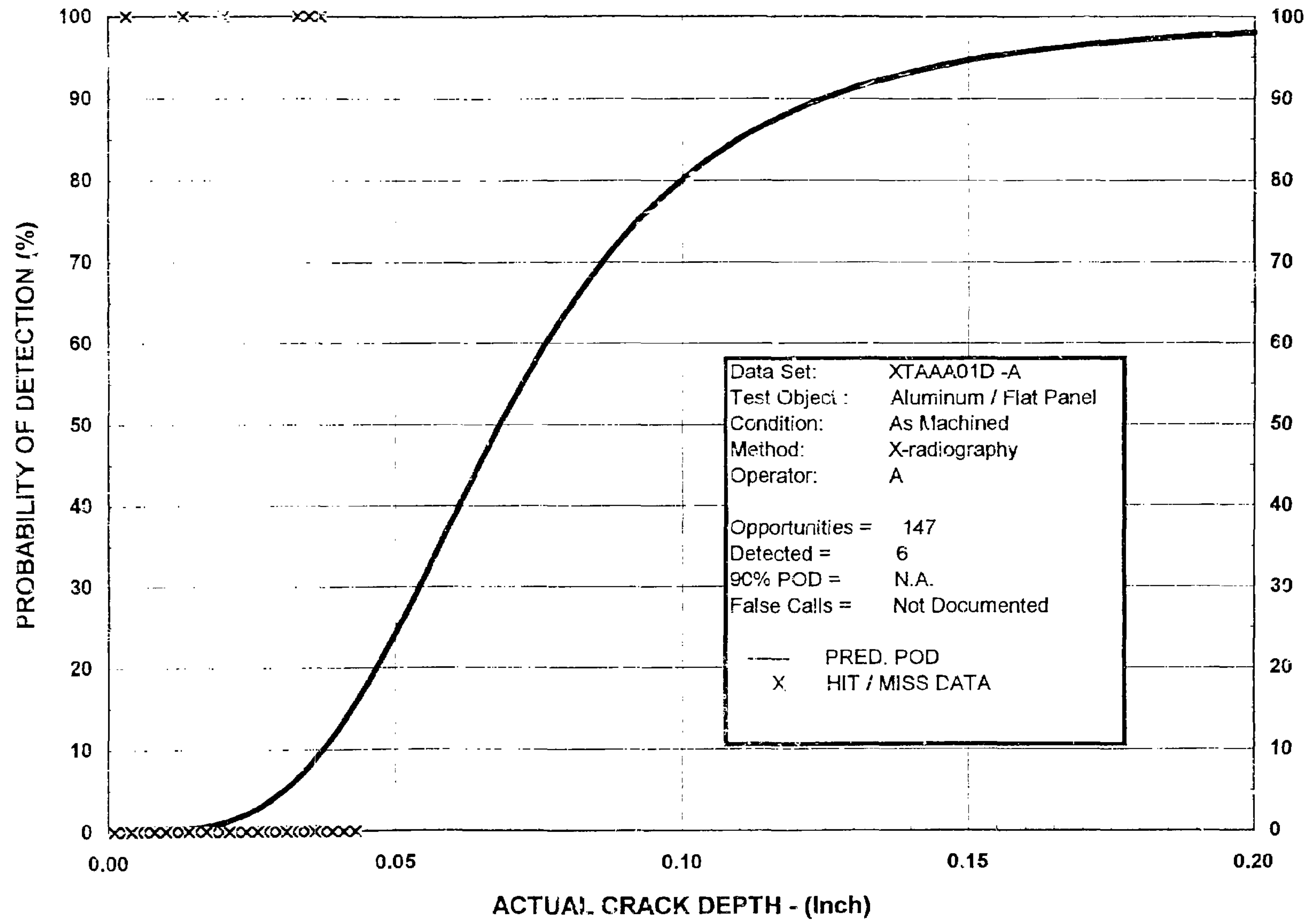


XT - 01 (1)B CRACK LENGTH

6/95

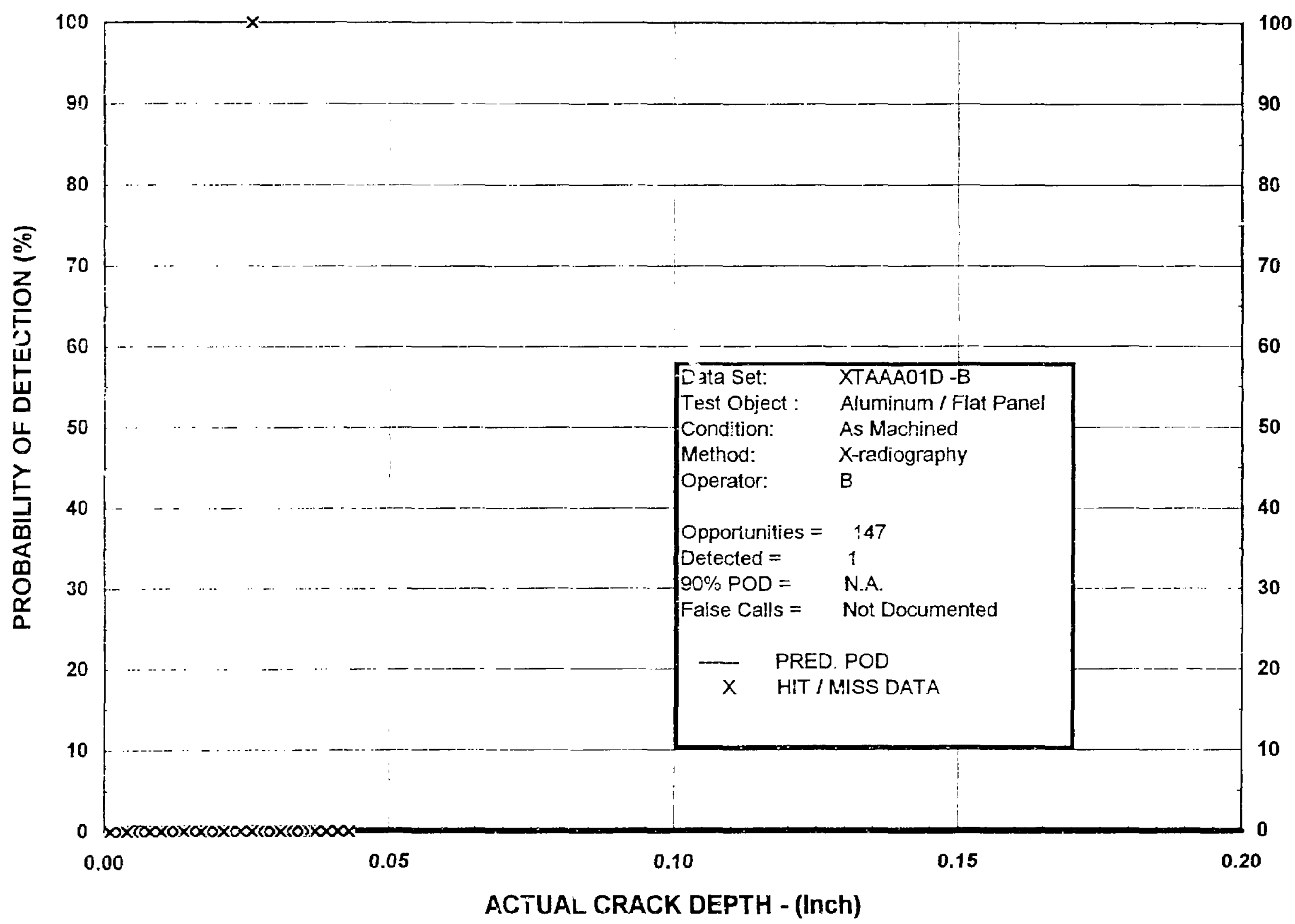
0.220 Inch Nominal Panel Thickness - XTAAA03L-C

XT - 01 (1)A CRACK DEPTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiography / automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,"After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	X-radiography / Kodak AA Film, Manual Read
DATA SET IDENTIFIER:	XTAAA01D-A,B,C; XTAAA02D-A,B,C; XTAAA03D-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	147 Cracks
DETECTED:	XTAAA01D-A= 6, B= 1, C= 2; 02D-A= 81, B= 87, C= 87; 03D-A= 100, B= 9[illegible], C= 88
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.
	90% POD Depth - "AS MACHINED" "AFTER ETCH" "AFTER PROOF"
	A= N.A. A= 0.037 in. A= 0.028 in.
	B= N.A. B= 0.033 in. B= 0.024 in.
	C= N.A. C= 0.037 in. C= 0.024 in.



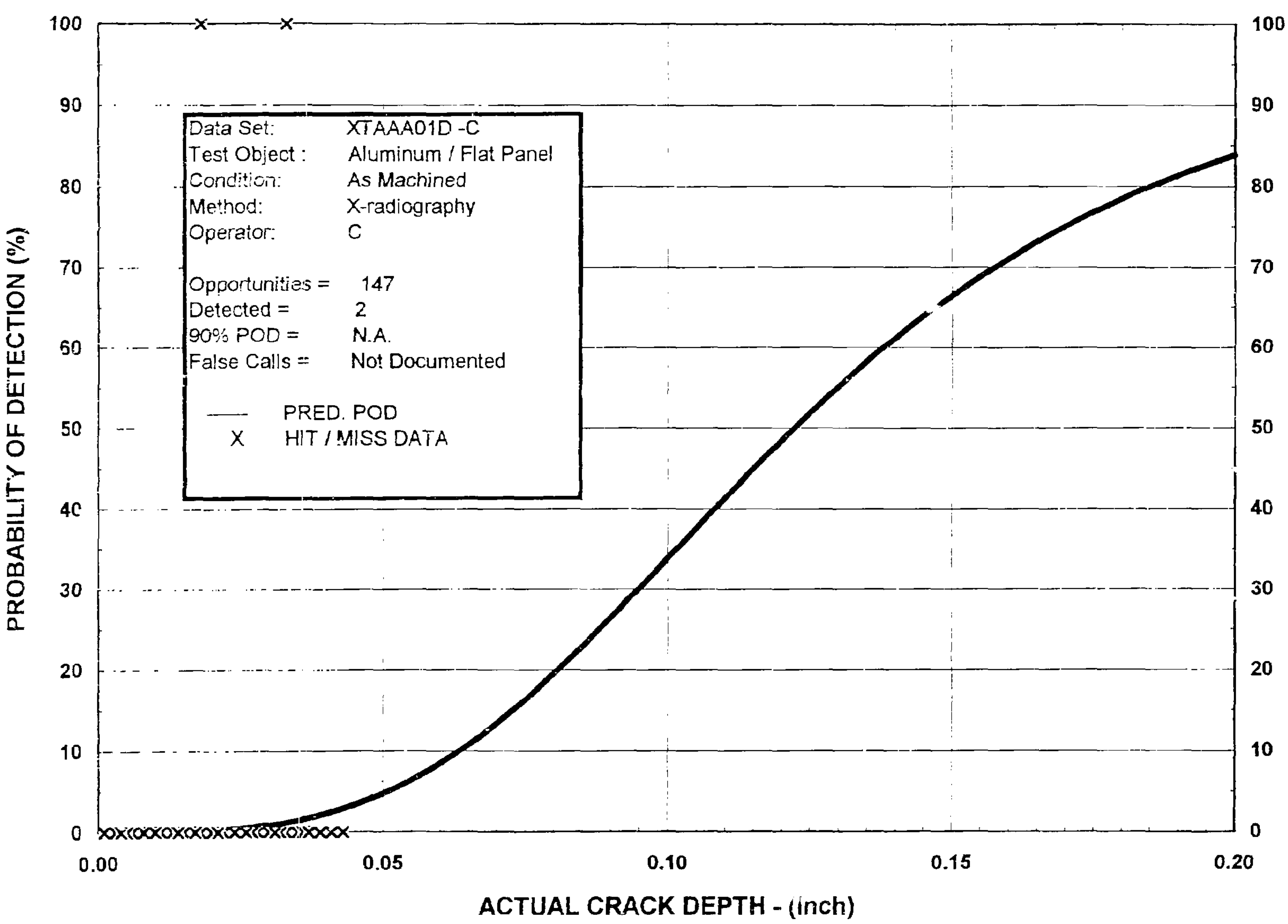
XT - 01 (1)A CRACK DEPTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01D-A



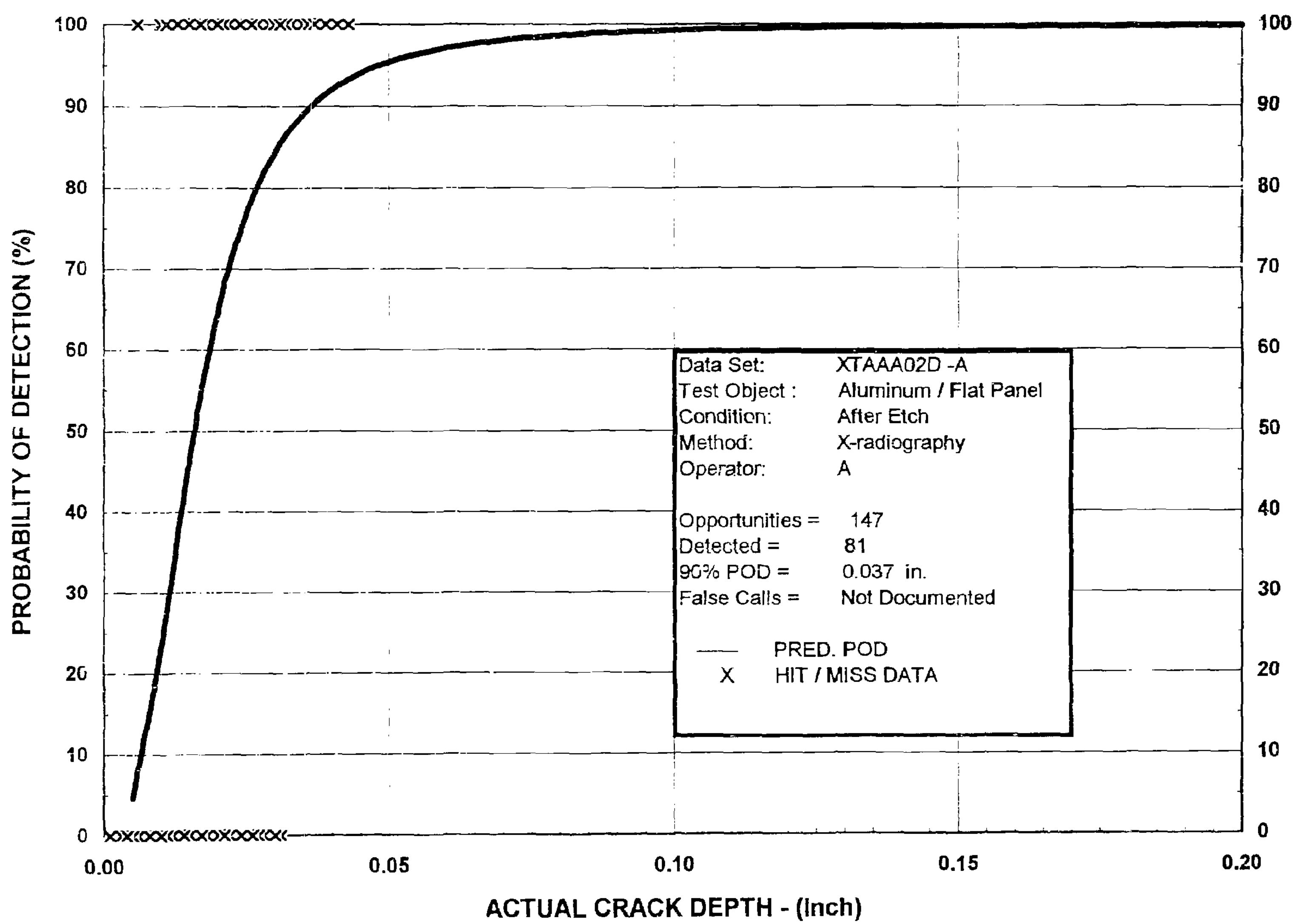
XT - 01 (1)A CRACK DEPTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01D-B



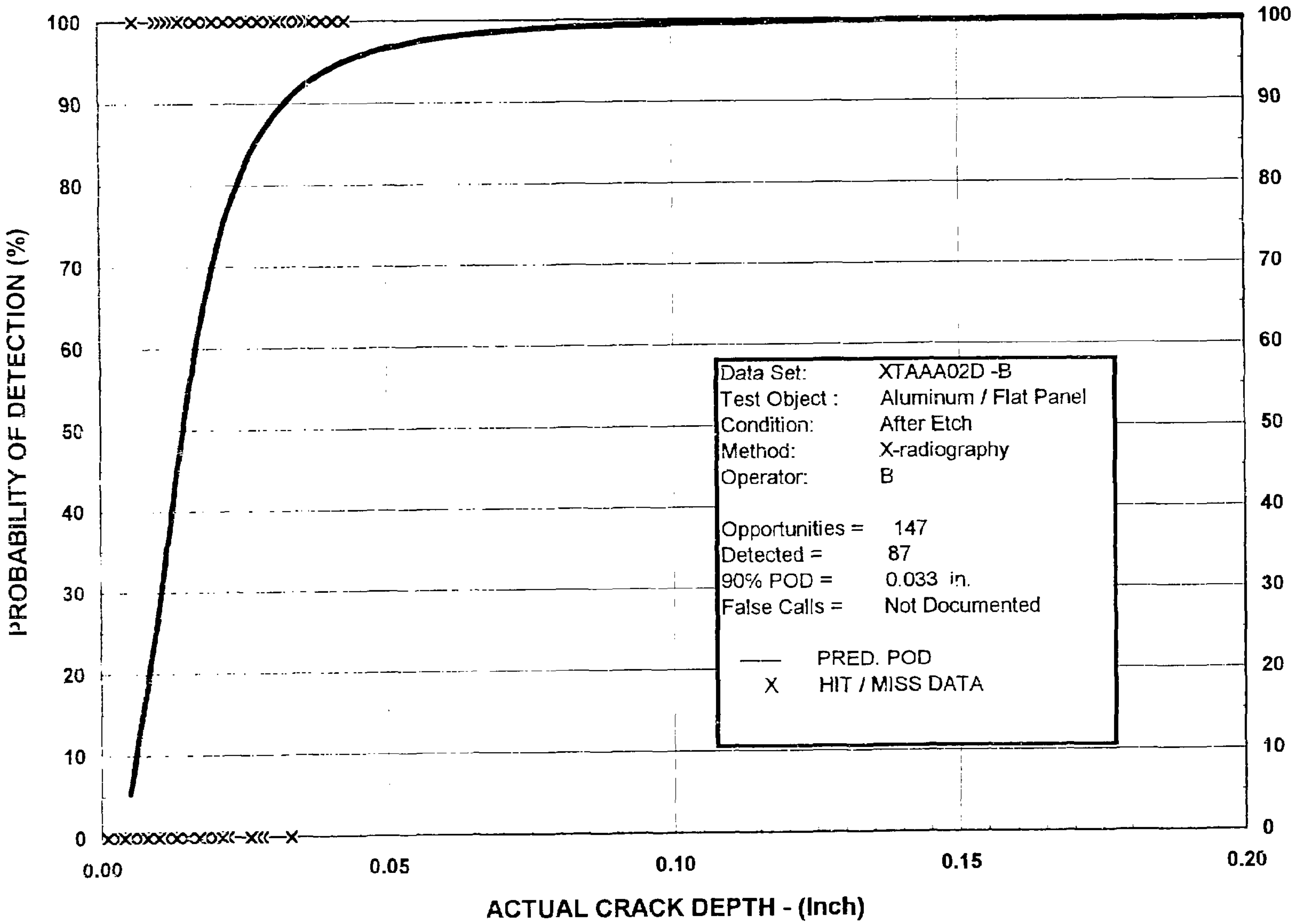
XT - 01 (1)A CRACK DEPTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA01D-C



XT - 01 (1)A CRACK DEPTH
6/95

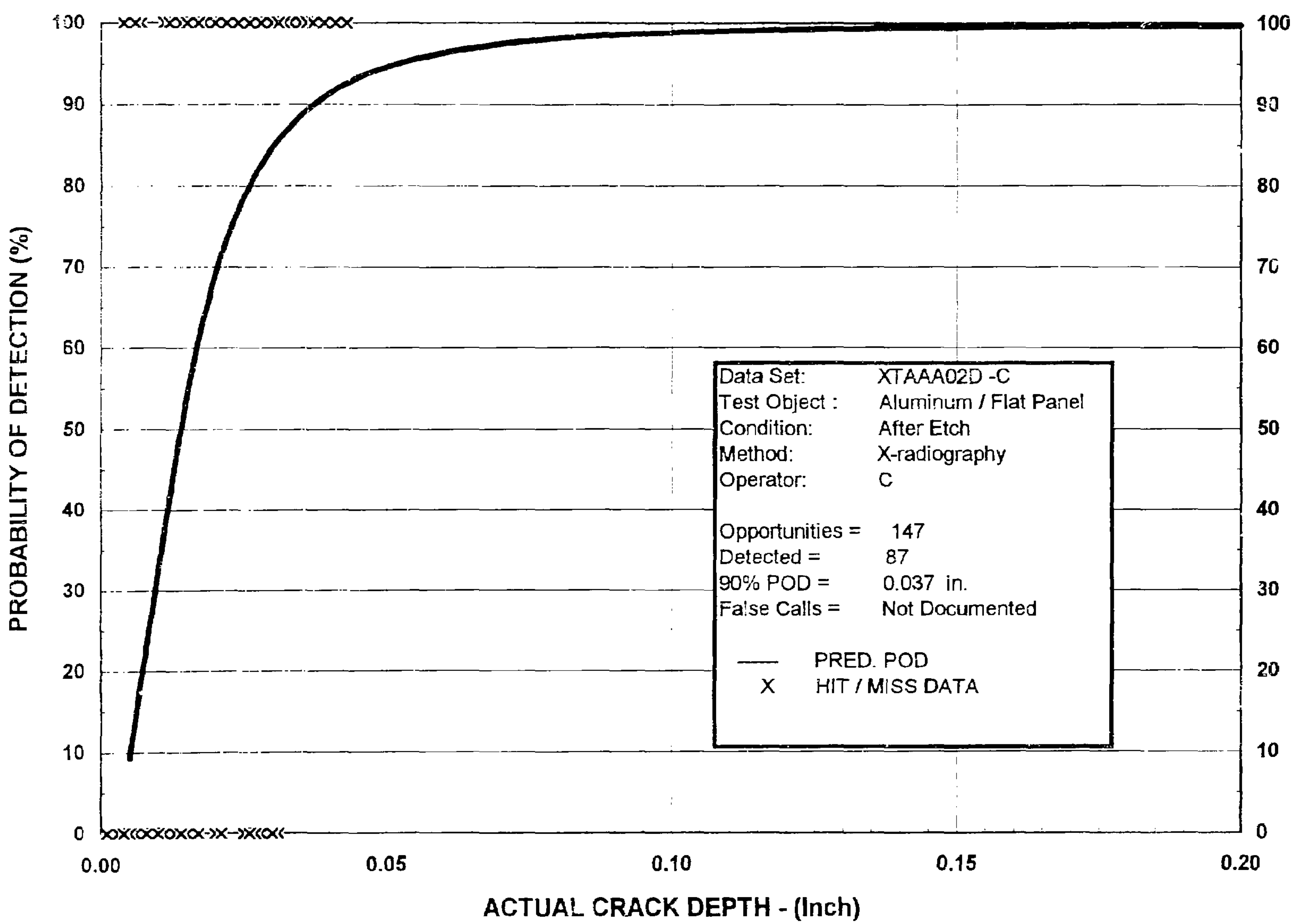
0.060 Inch Nominal Panel Thickness - XTAAA02D-A



XT - 01 (1)A CRACK DEPTH

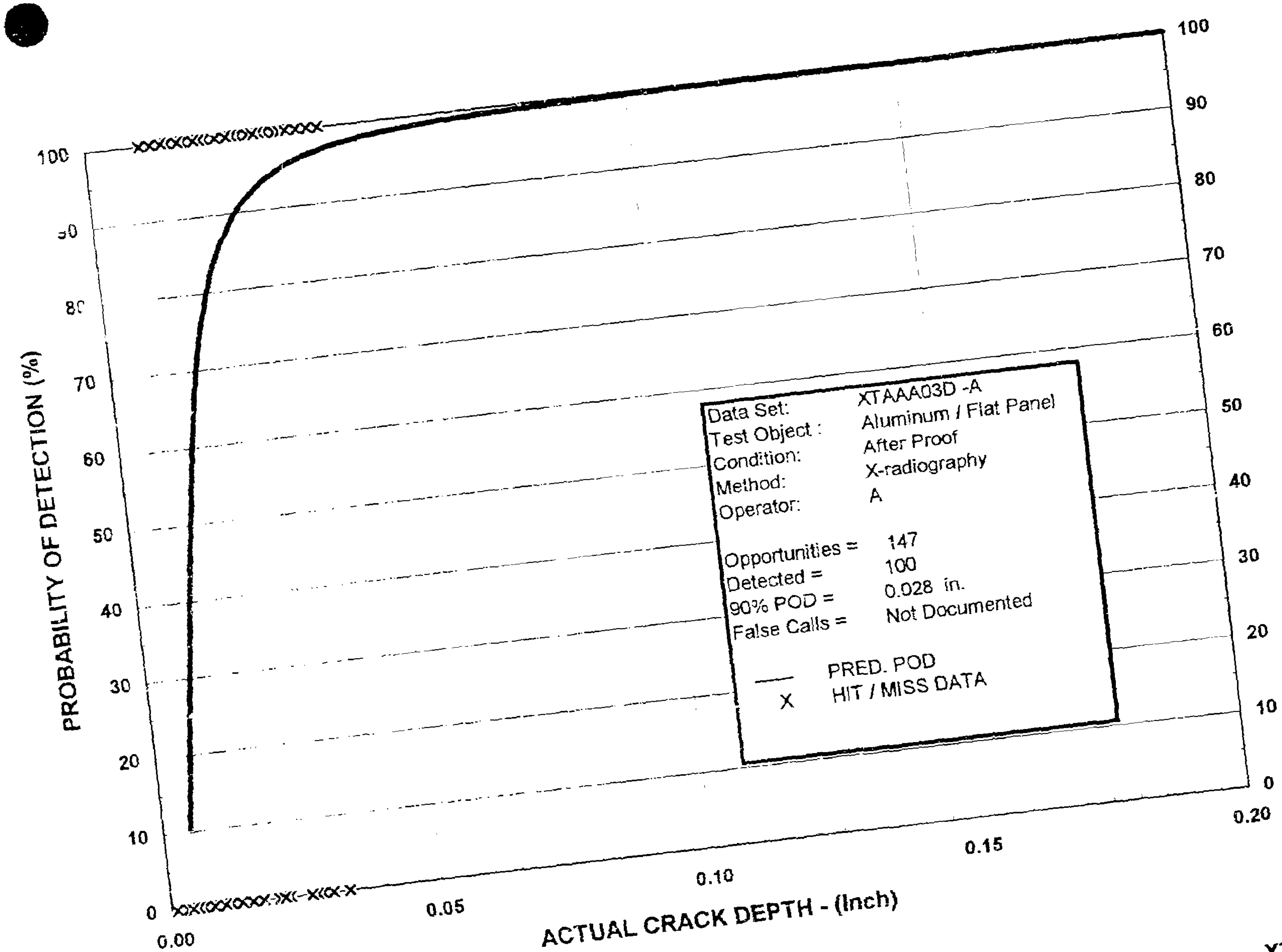
6/95

0.060 Inch Nominal Panel Thickness - XTAAA02D-B



XT - 01 (1)A CRACK DEPTH
6/95

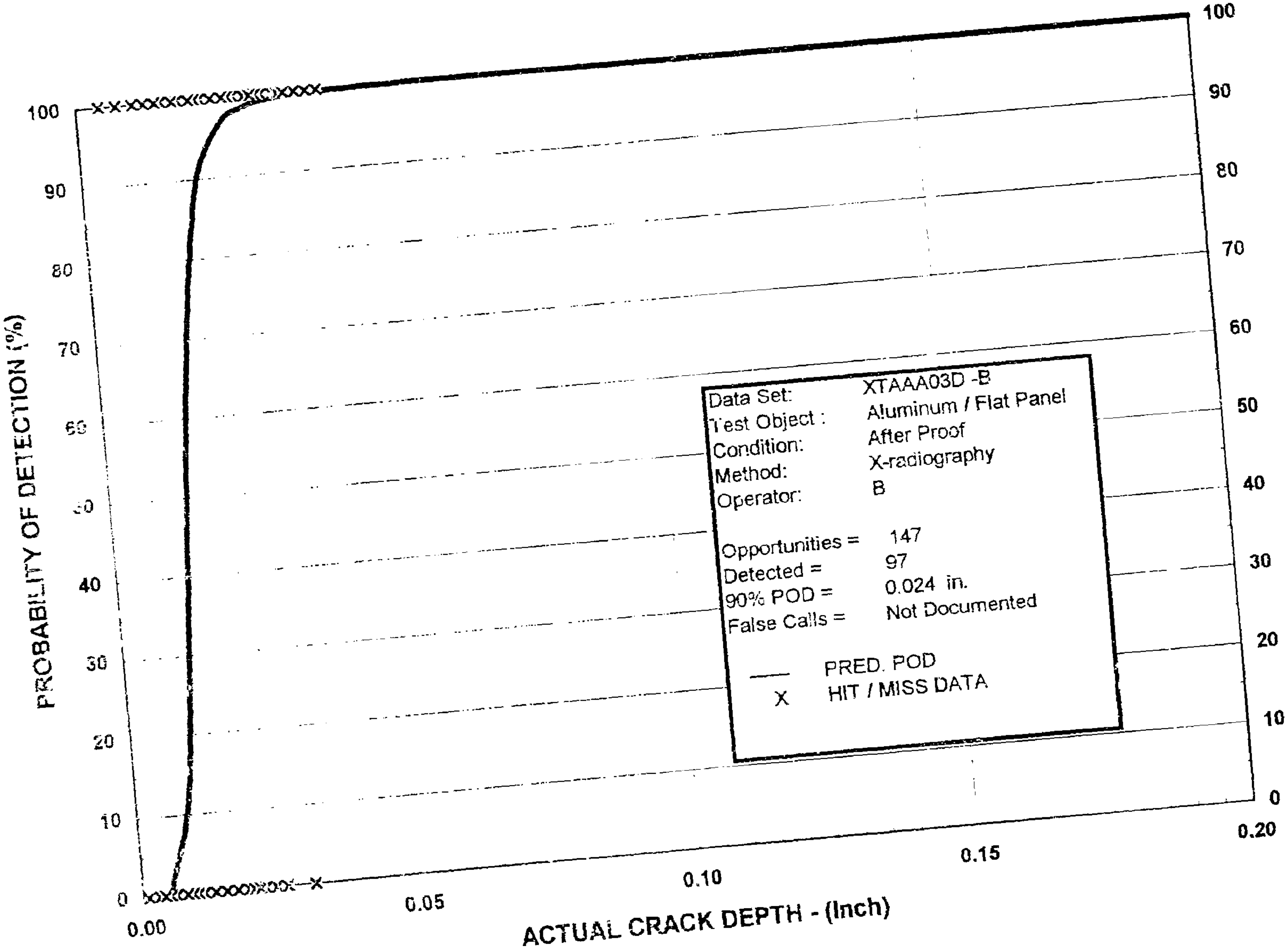
0.060 Inch Nominal Panel Thickness - XTAAA02D-C



0.060 Inch Nominal Panel Thickness - XTAAA03D-A

XT - 01 (1)A CRACK DEPTH

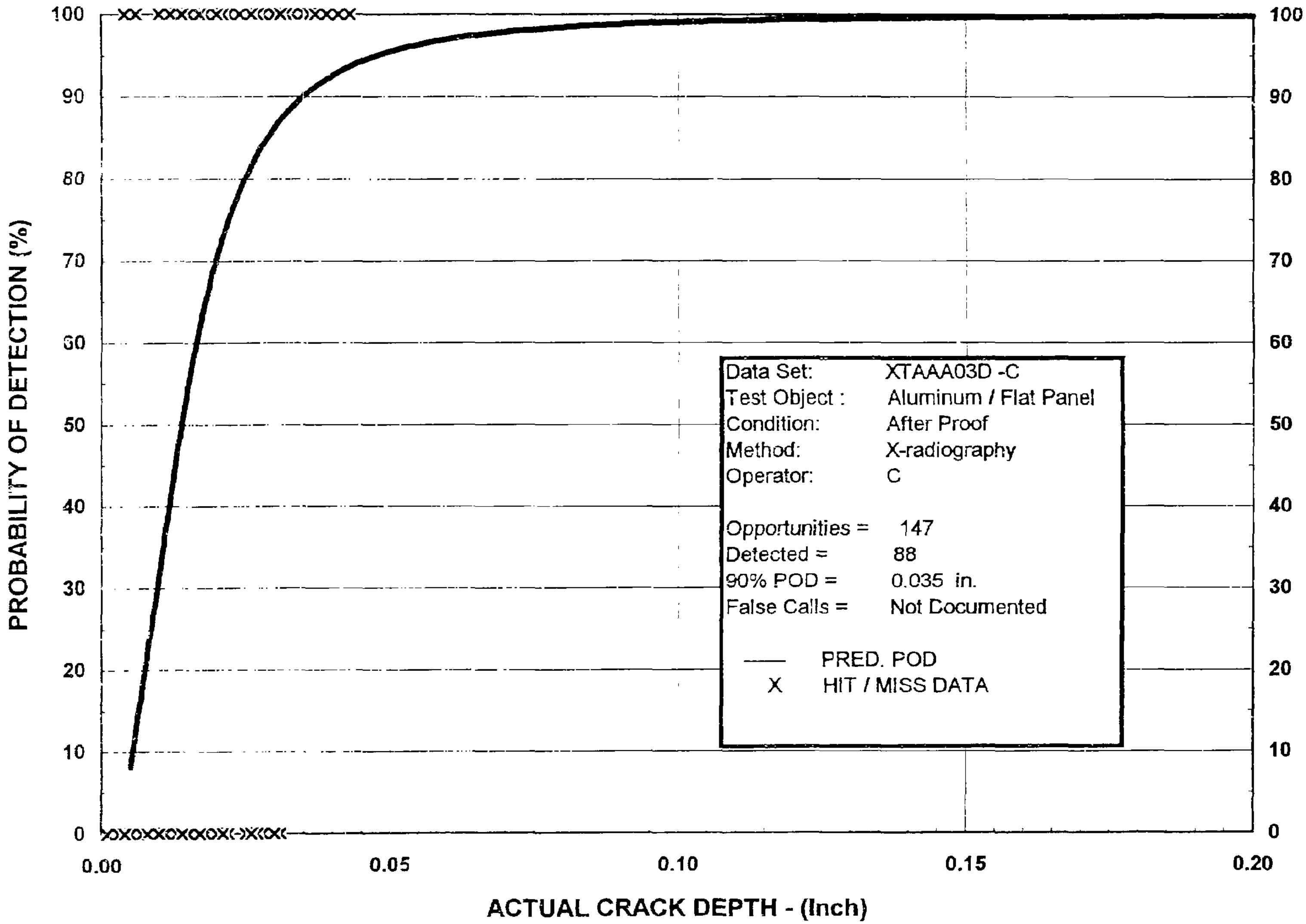
6/95



0.060 Inch Nominal Panel Thickness - XTAAA03D-B

XT - 01 (1)A CRACK DEPTH

6/95



XT - 01 (1)A CRACK DEPTH
6/95

0.060 Inch Nominal Panel Thickness - XTAAA03D-C

XT - 01 (1)B CRACK DEPTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiography / automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.220 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined", -02,"After Etch", -03,"After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	X-radiography / Kodak AA Film, Manual Read
DATA SET IDENTIFIER:	XTAAA01D-A,B,C; XTAAA02D-A,B,C; XTAAA03D-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	164 / 159 Cracks (Some cracks lost in proof test)
DETECTED:	XTAAA01D-A= 27, B= 25, C= 32; 02D-A= 68, B= 85, C= 77; 03D-A= 85, B= 84, C= 89
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
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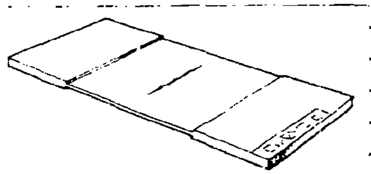
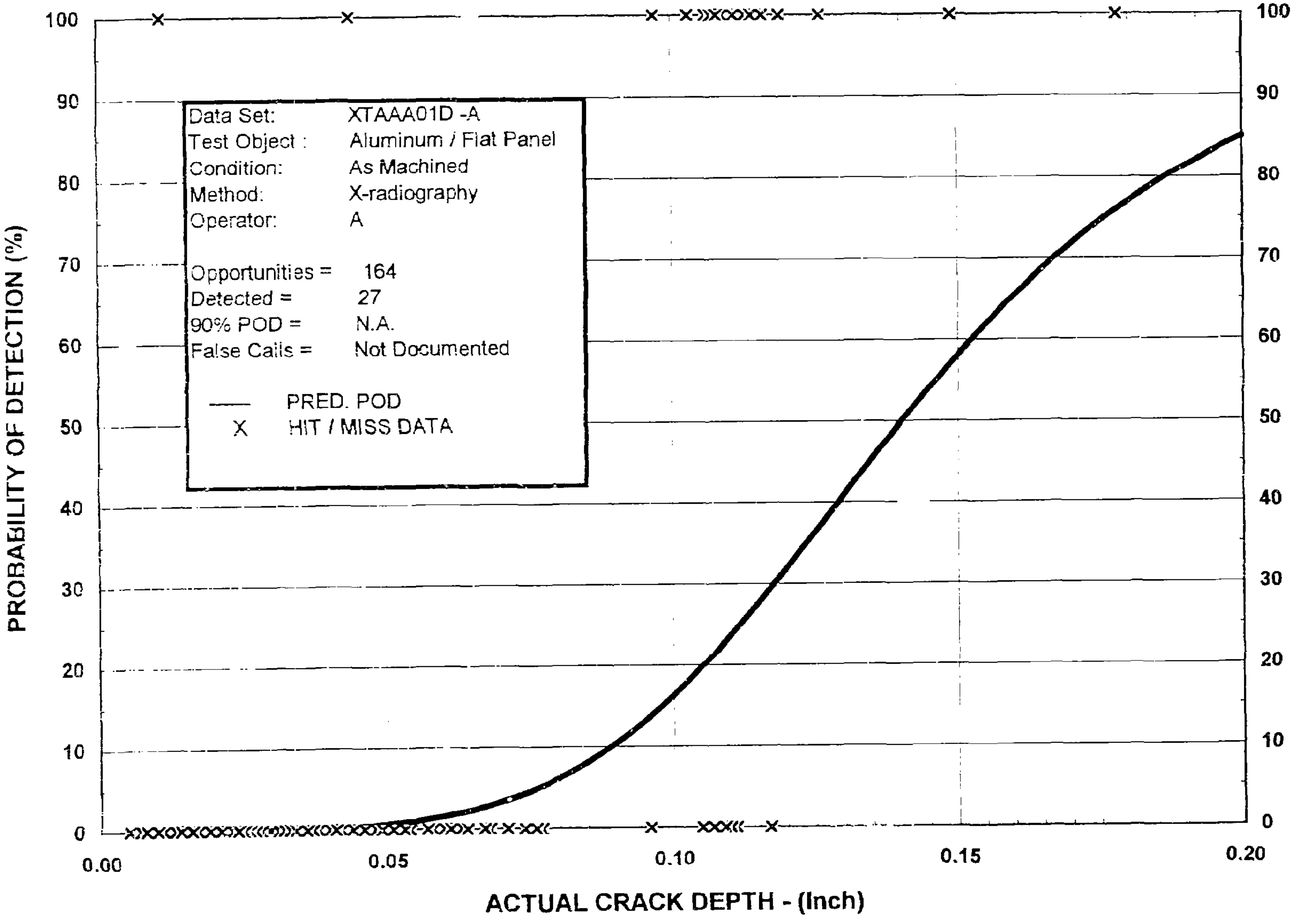
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.

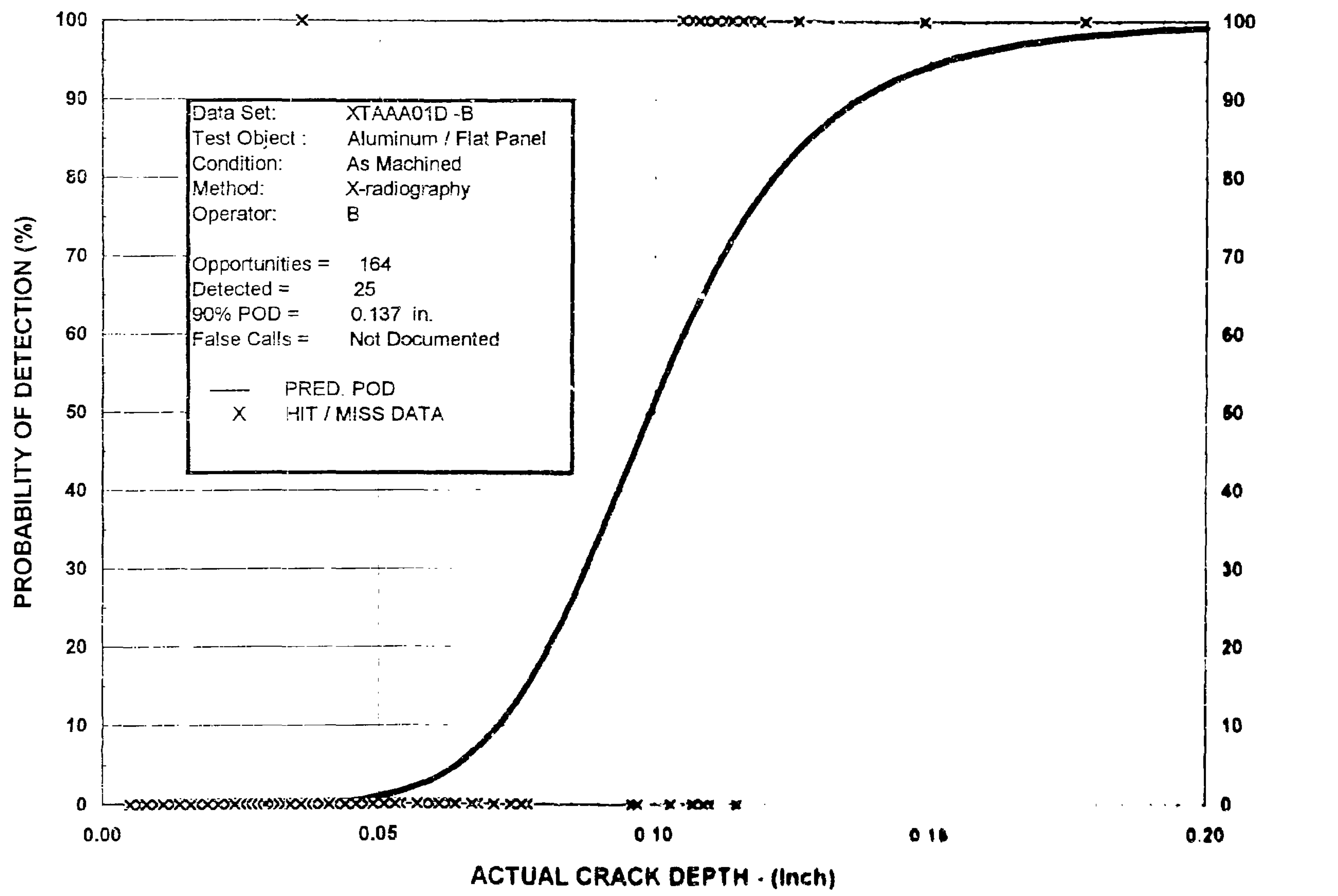


90% POD Depth -	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
	A= N.A.	A= 0.127 in.	A= 0.077 in.
	B= 0.137 in.	B= 0.086 in.	B= 0.079 in.
	C= 0.184 in.	C= 0.122 in.	C= 0.053 in.



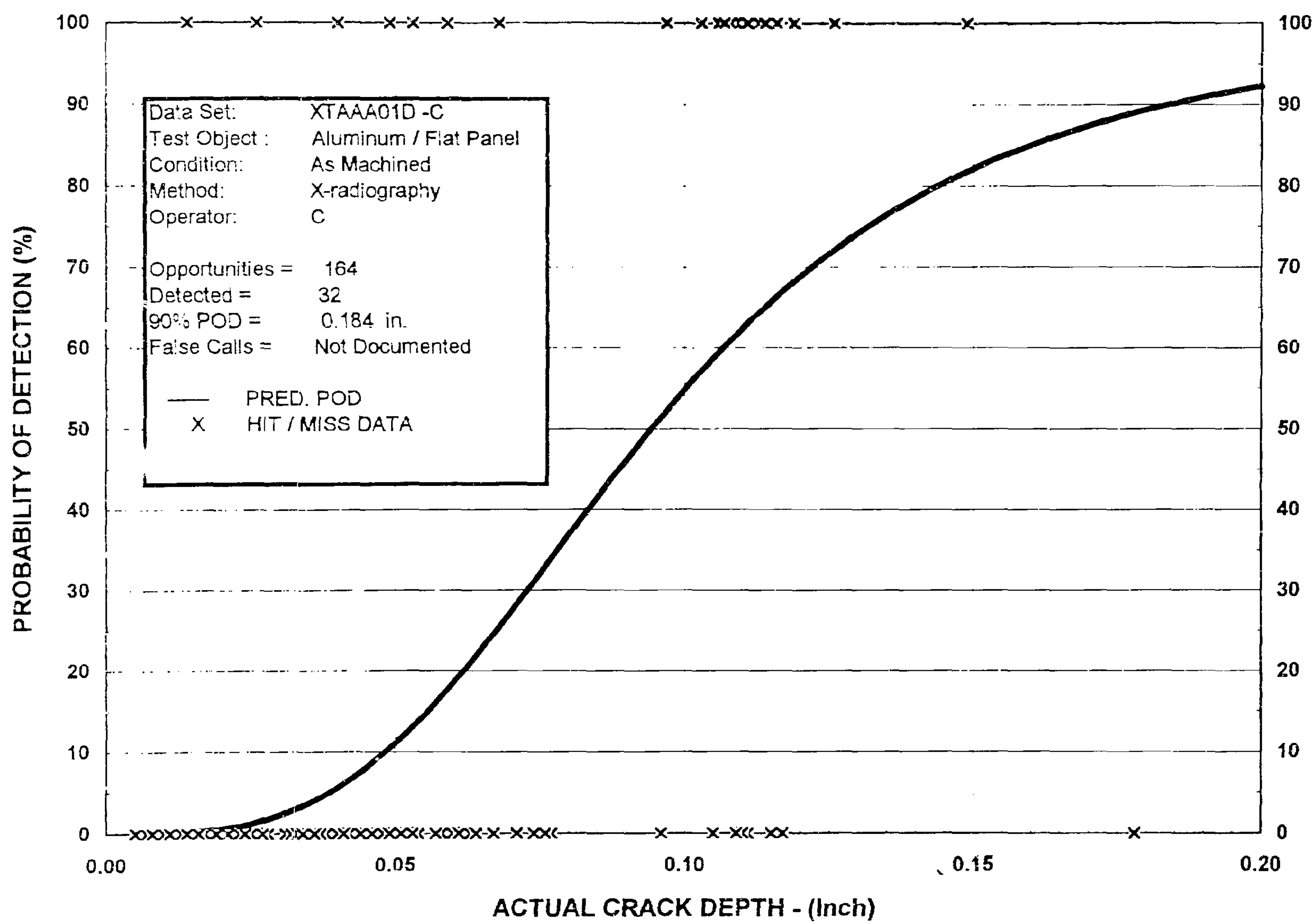
XT - 01 (1)B CRACK DEPTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA01D-A



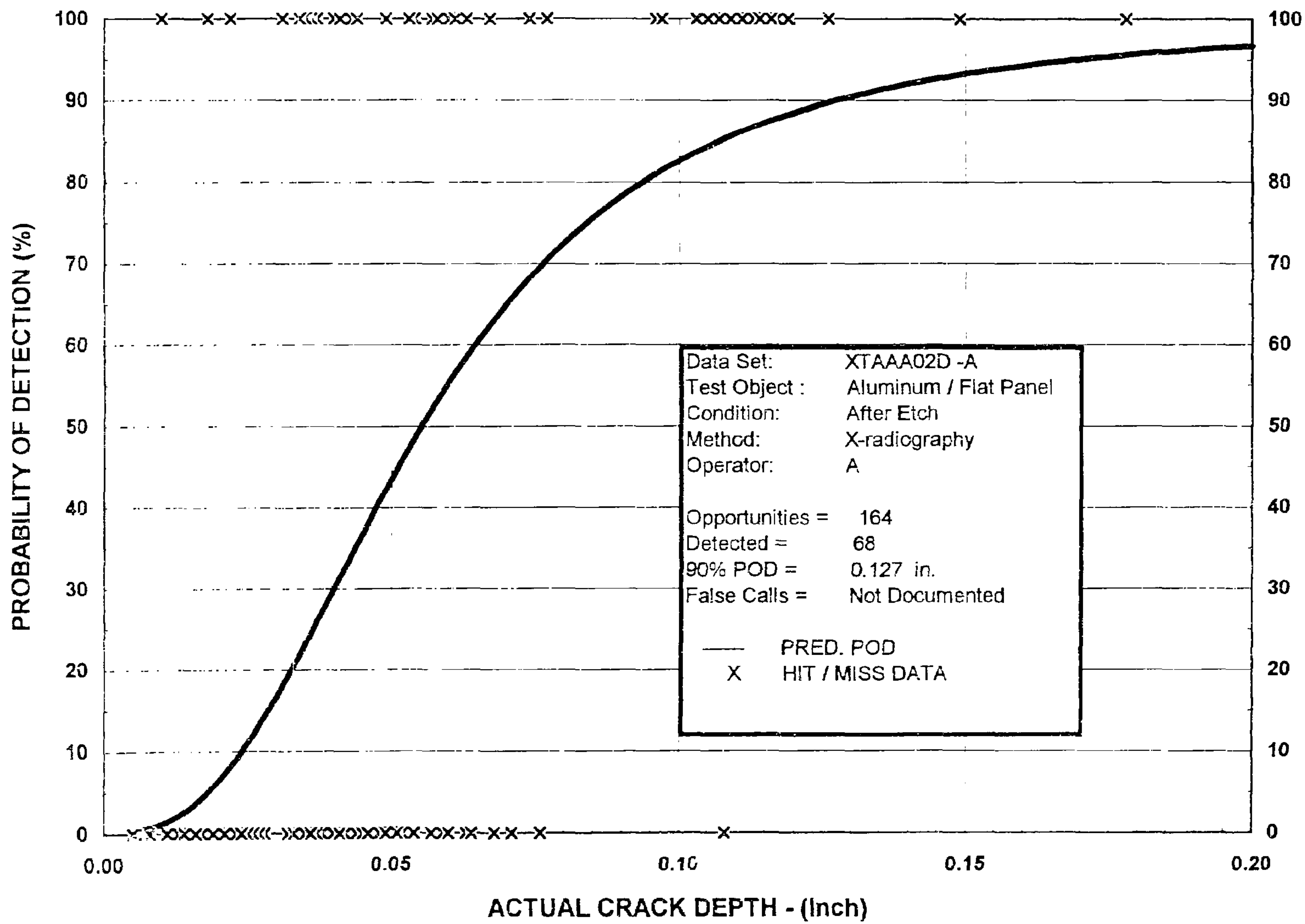
XT - 01 (1)B CRACK DEPTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA01D-B



XT - 01 (1)B CRACK DEPTH
6/95

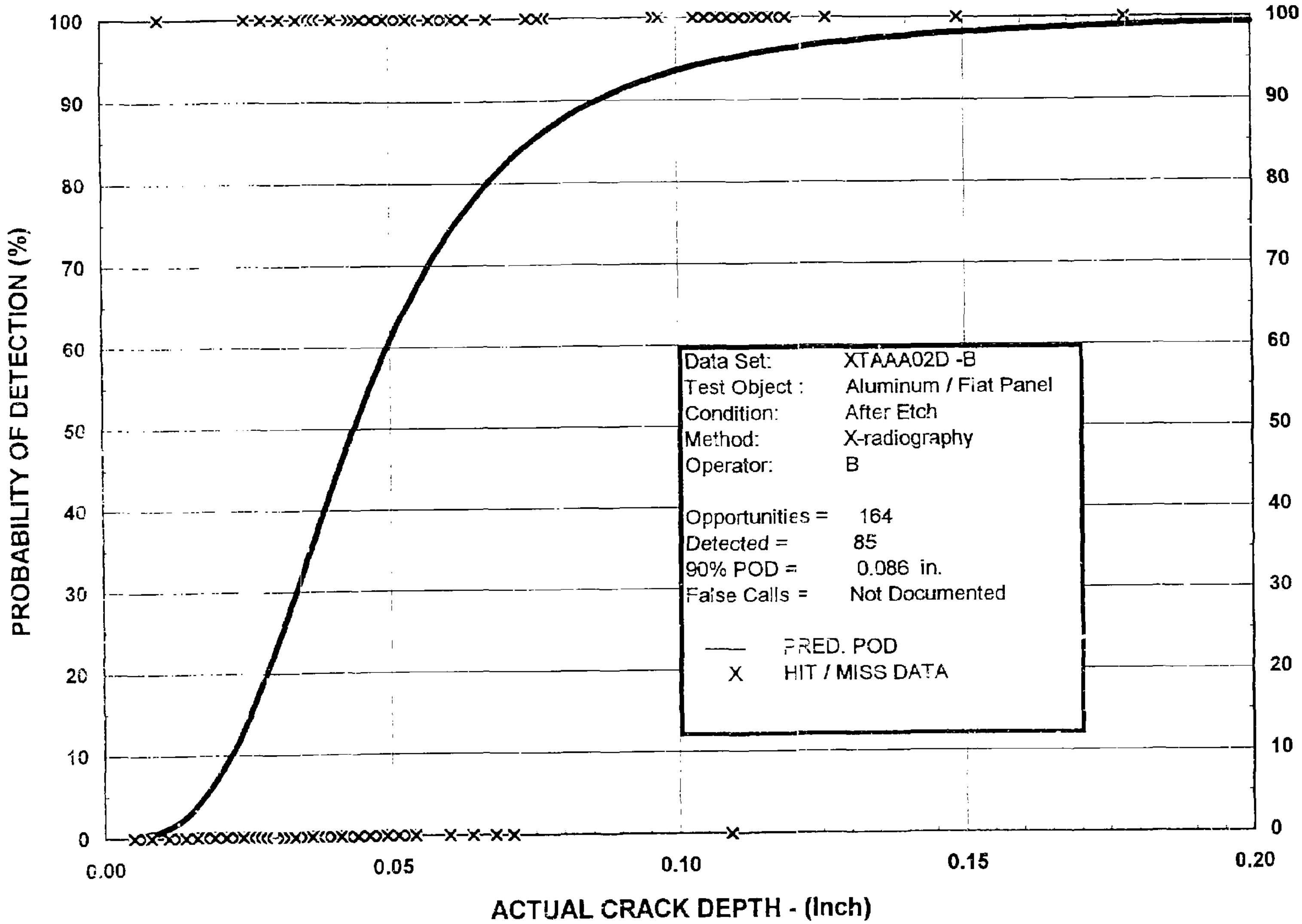
0.220 Inch Nominal Panel Thickness - XTAAA01D-C



XT - 01 (1)B CRACK DEPTH

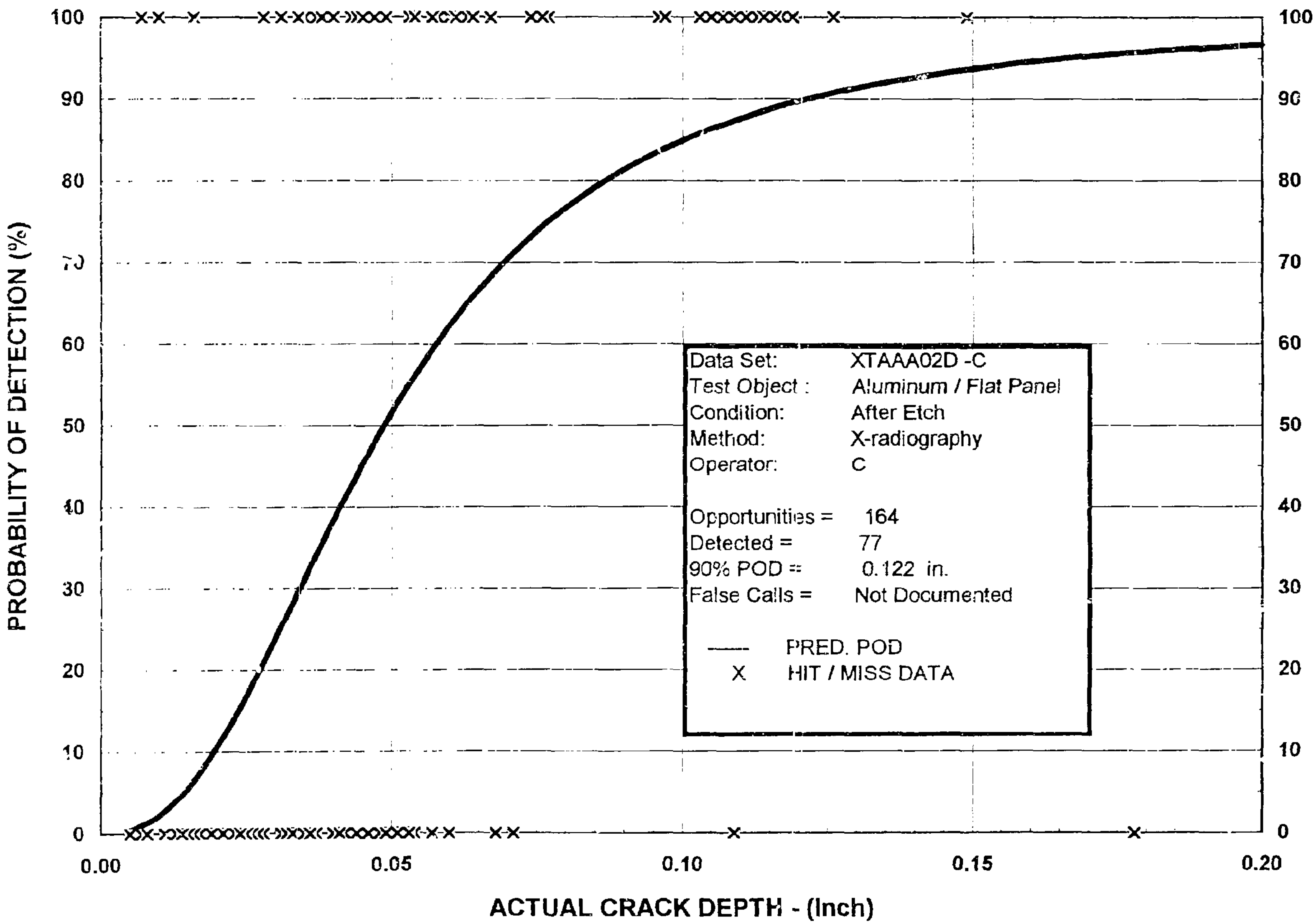
6/95

0.220 Inch Nominal Panel Thickness - XTAAA02D-A



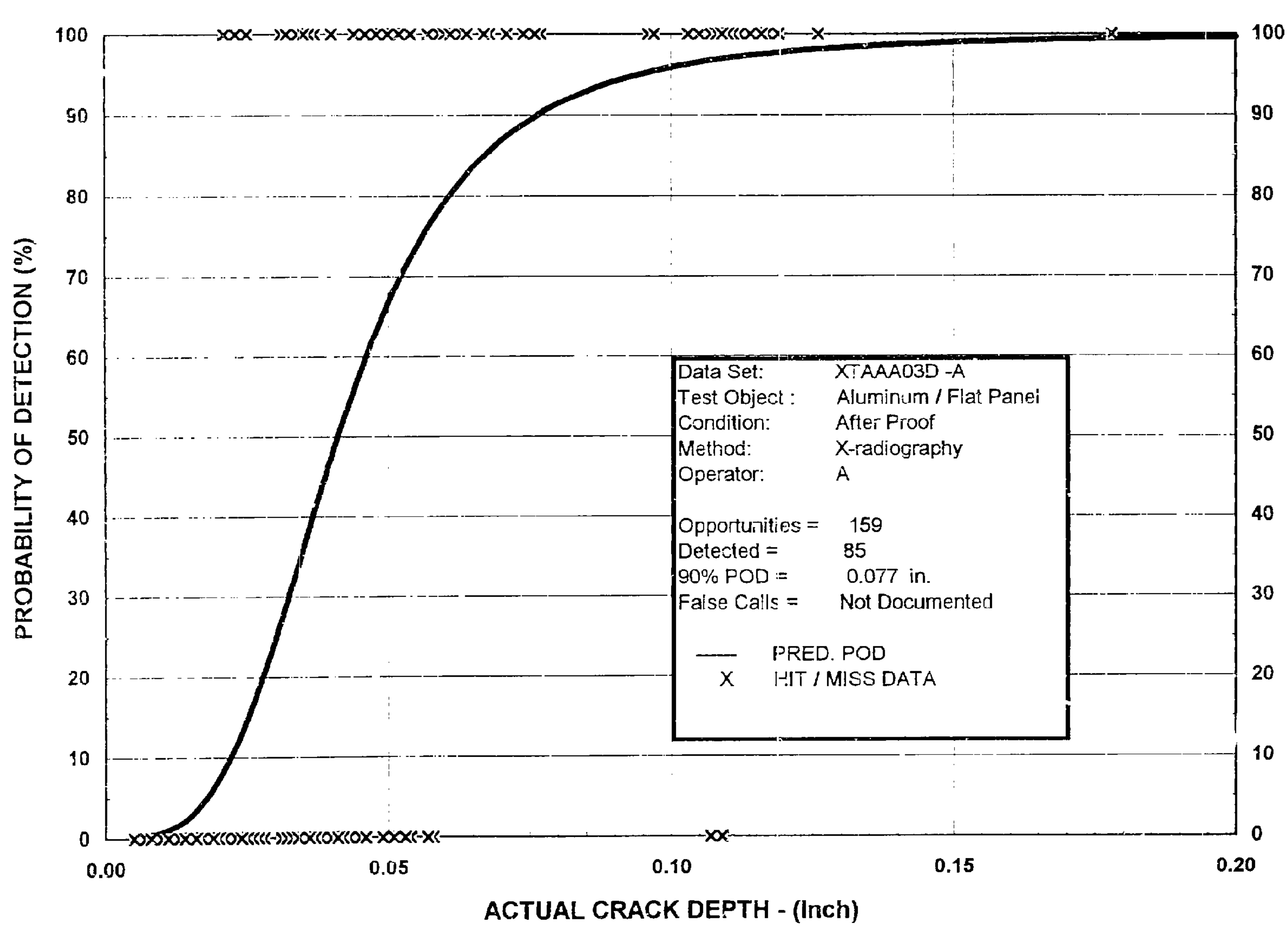
XT - 01 (1)B CRACK DEPTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA02D-B



XT - 01 (1)B CRACK DEPTH
6/95

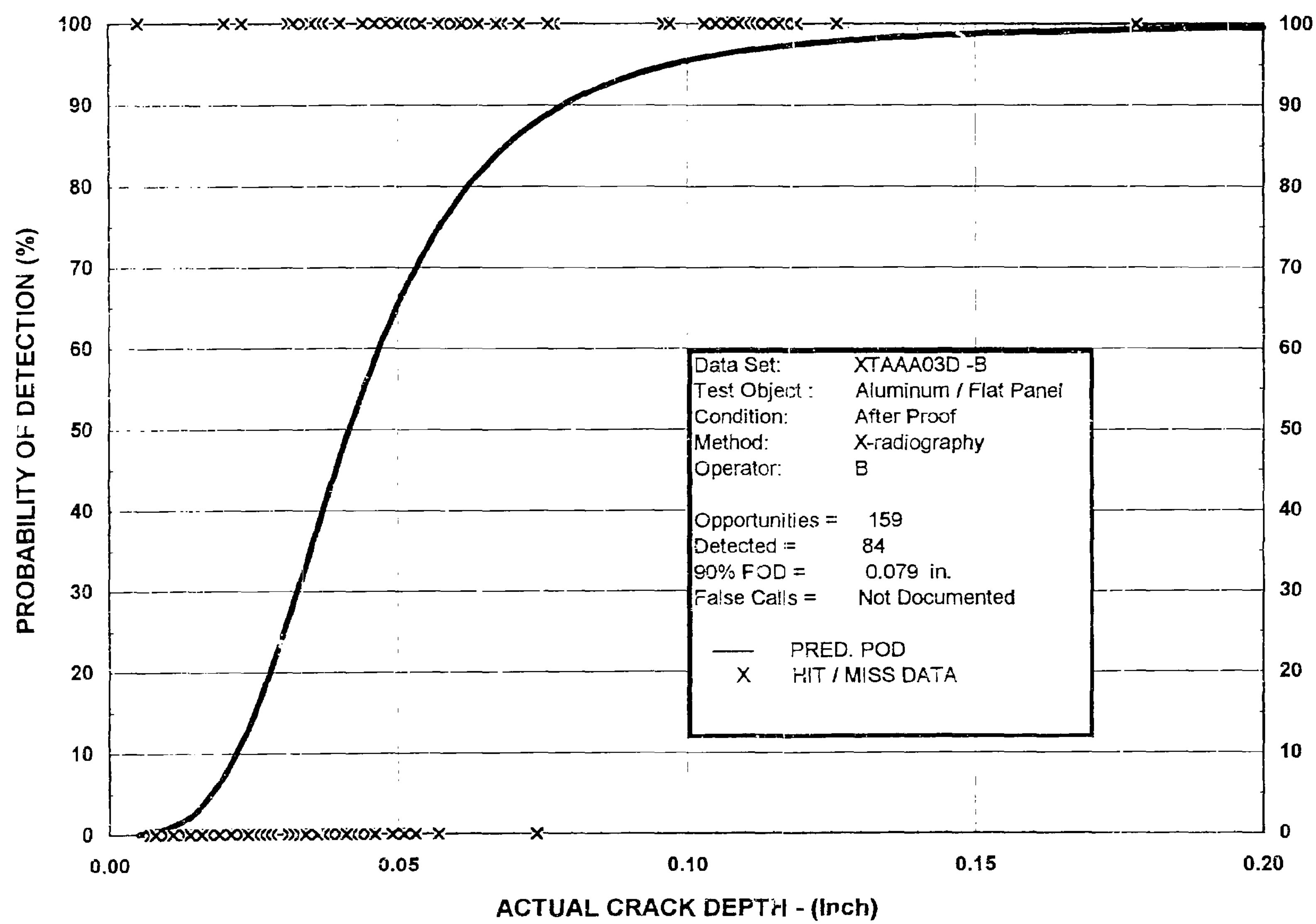
0.220 Inch Nominal Panel Thickness - XTAAA02D-C



XT - 01 (1)B CRACK DEPTH

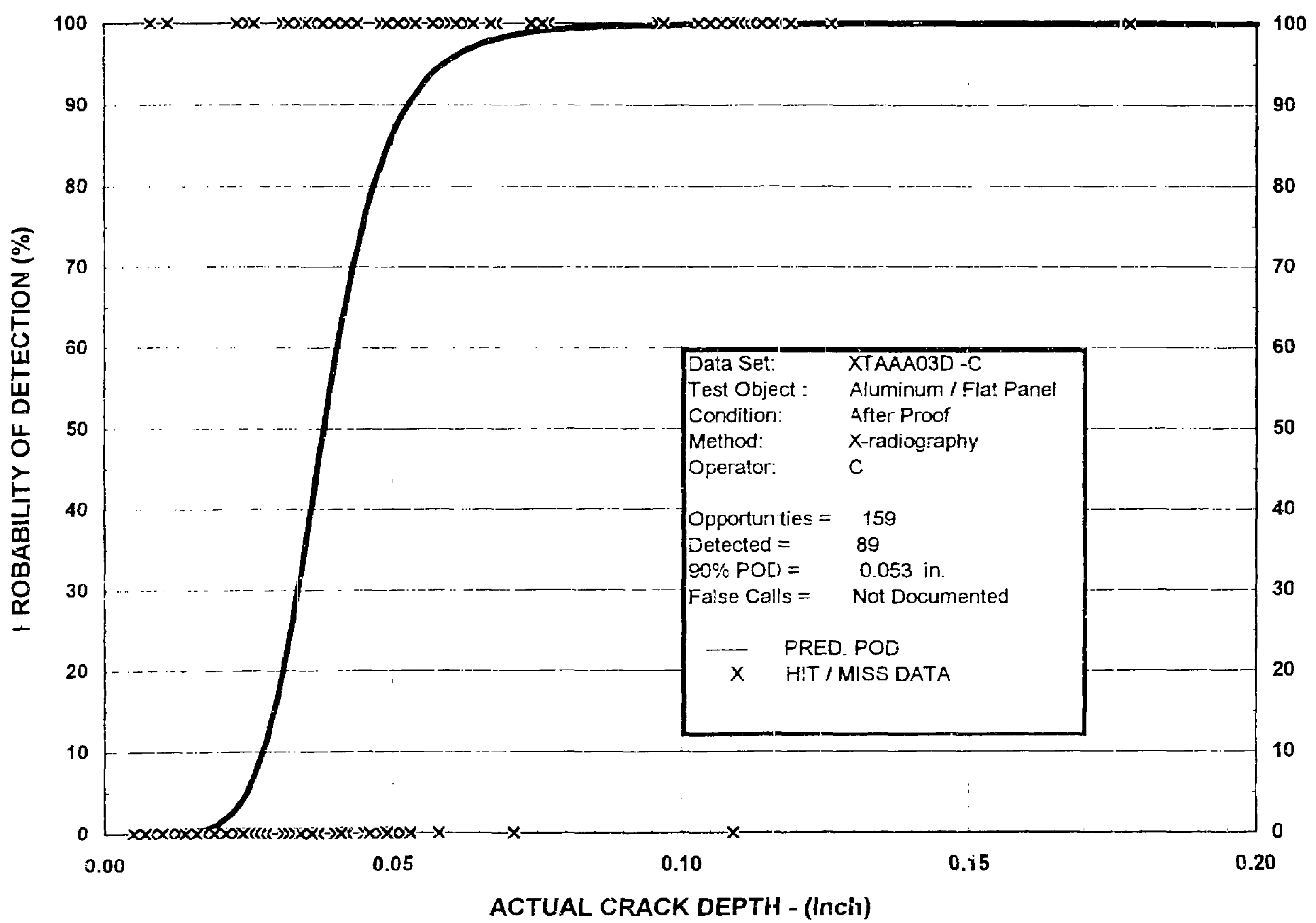
6/95

0.220 Inch Nominal Panel Thickness - XTAAA03D-A



XT - 01 (1)B CRACK DEPTH
6/95

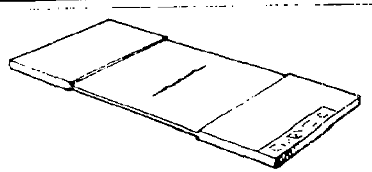
0.220 Inch Nominal Panel Thickness - XTAAA03D-B



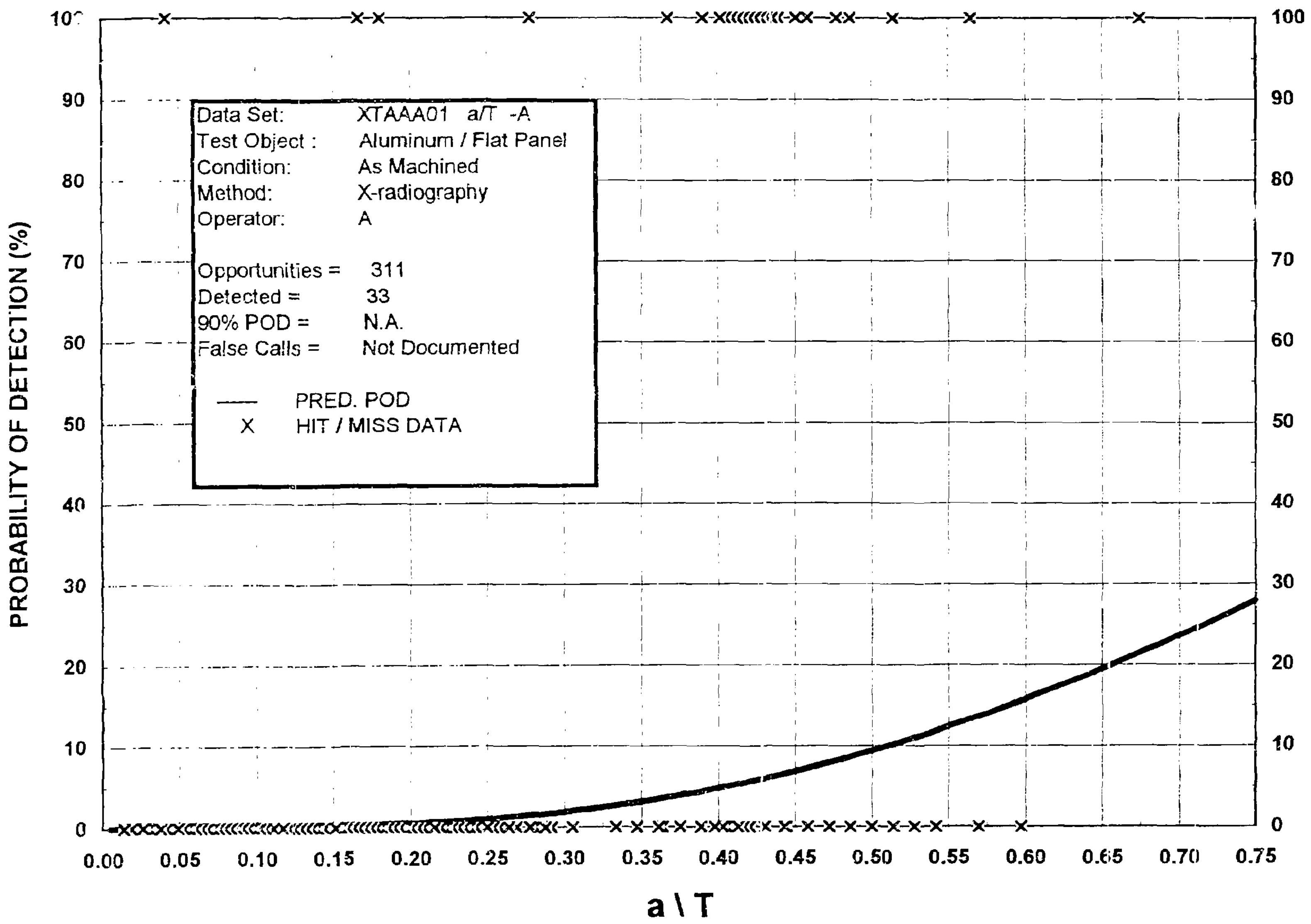
XT - 01 (1)B CRACK DEPTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAA03D-C

XRT - 01 (1)C, a/T	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiography - Kodak Type M / automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	"As Machined", "After Etch", "After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Manual Read / Manual Recording
DATA SET IDENTIFIER:	XTAAA01a/T-A,B,C; XTAAA02a/T-A,B,C; XTAAA03a/T-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	311 Cracks (01 and 02); 306 (03)
DETECTED:	XTAAA01a/T-A= 33, B= 26, C= 34; 02a/T-A= 149, B= 172, C= 164; 03a/T-A= 185, B= 181, C= 177
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 113 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.



90% POD	"AS MACHINED"	"AFTER ETCH"	"AFTER PROOF"
a/T	A= N.A.	A= 0.600	A= 0.396
	B= N.A	B= 0.479	B= 0.431
	C= N.A.	C= 0.593	C= 0.503

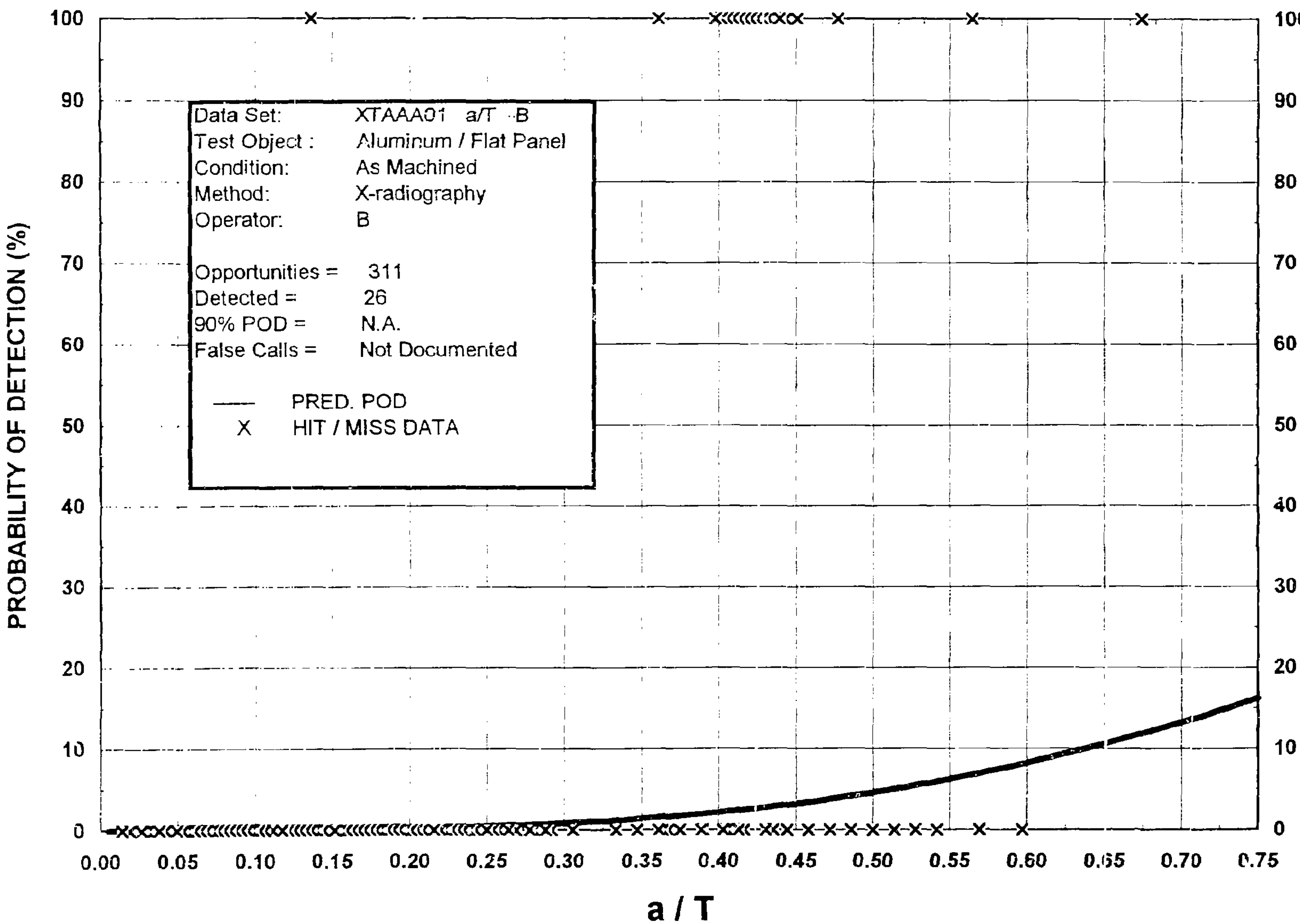


XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO

6/95

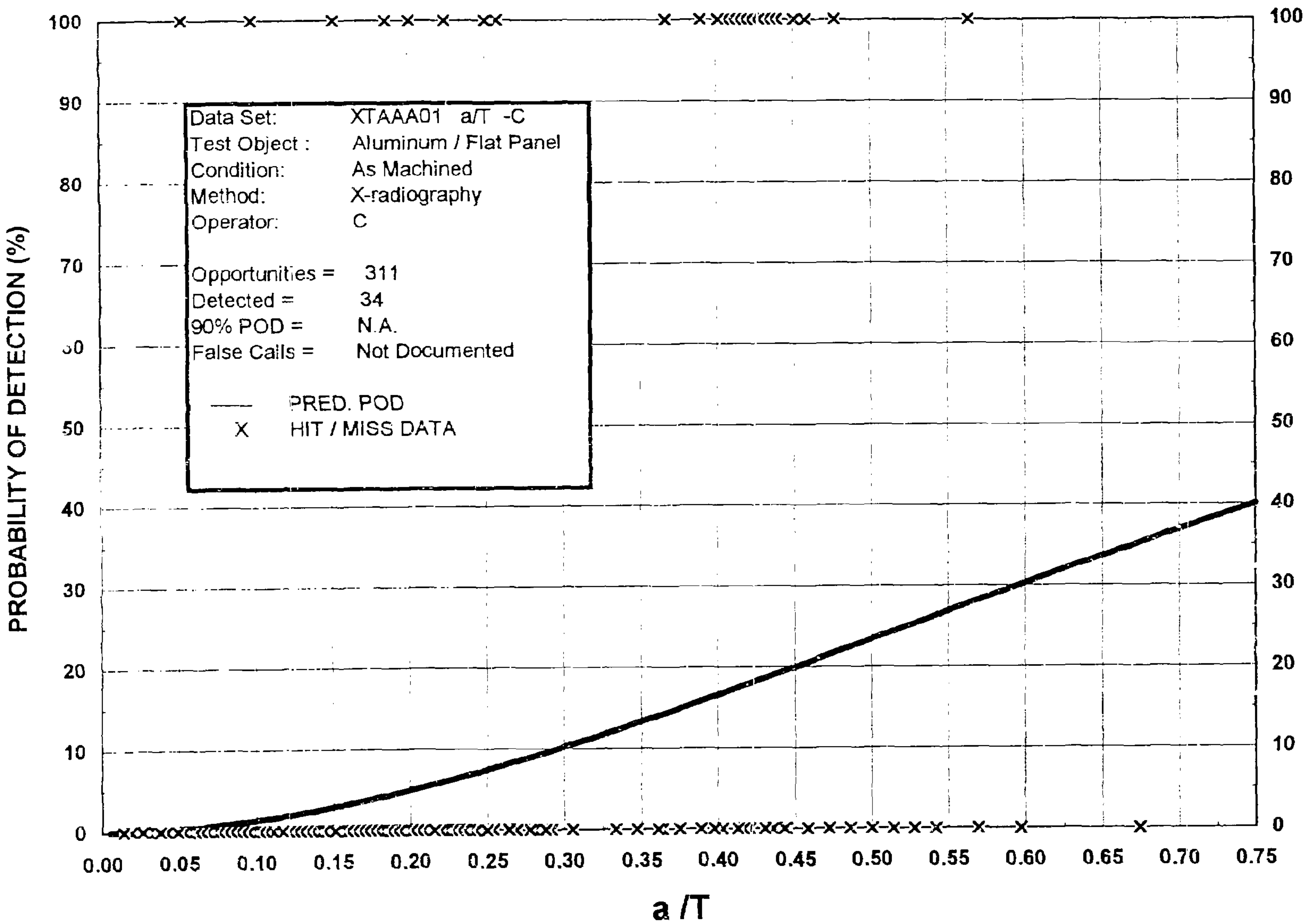
XTAAA01 a / T -A

FLAT PLATE ALUMINUM - OPERATOR A



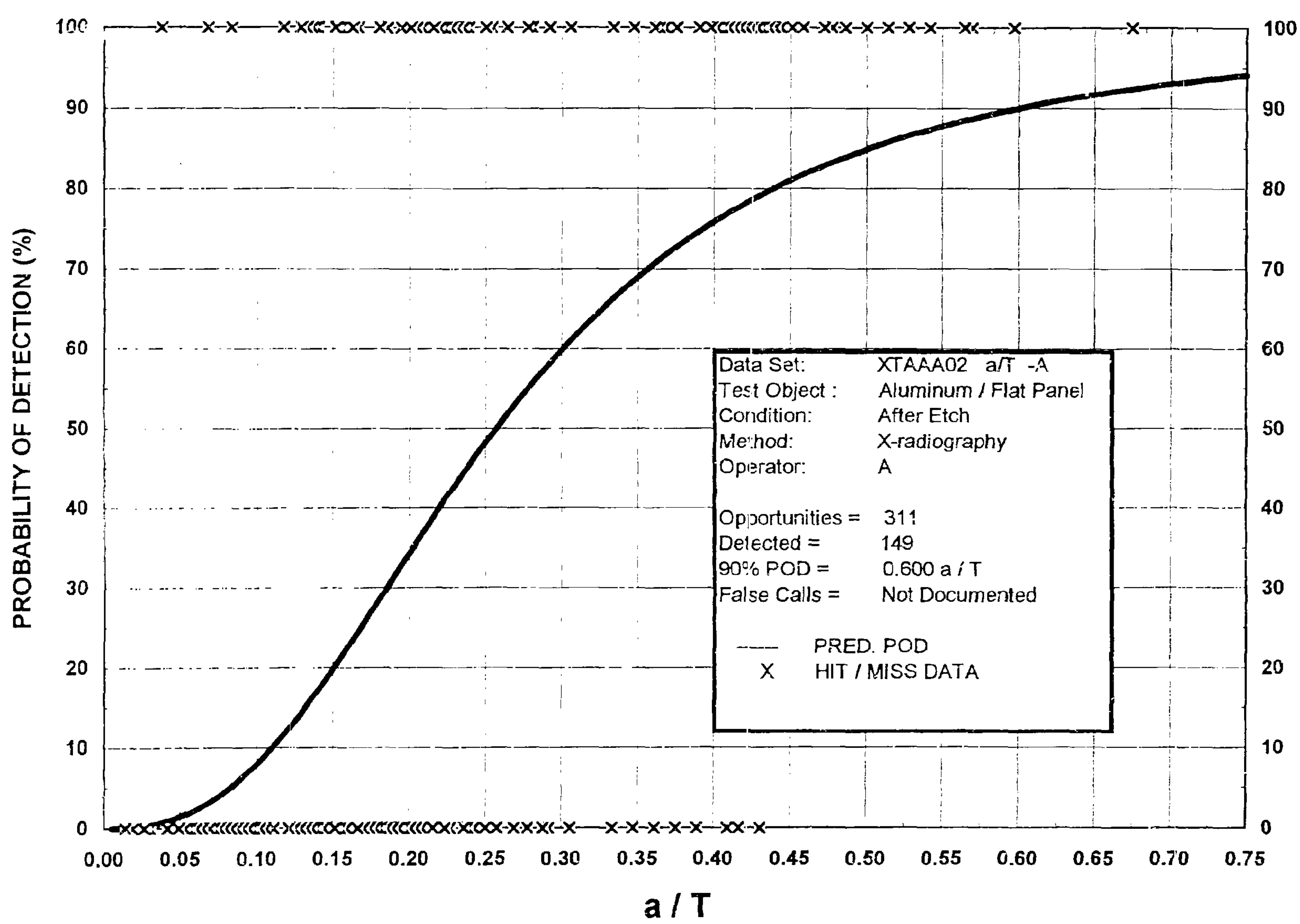
XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAA01 a / T -B
FLAT PLATE ALUMINUM - OPERATOR B



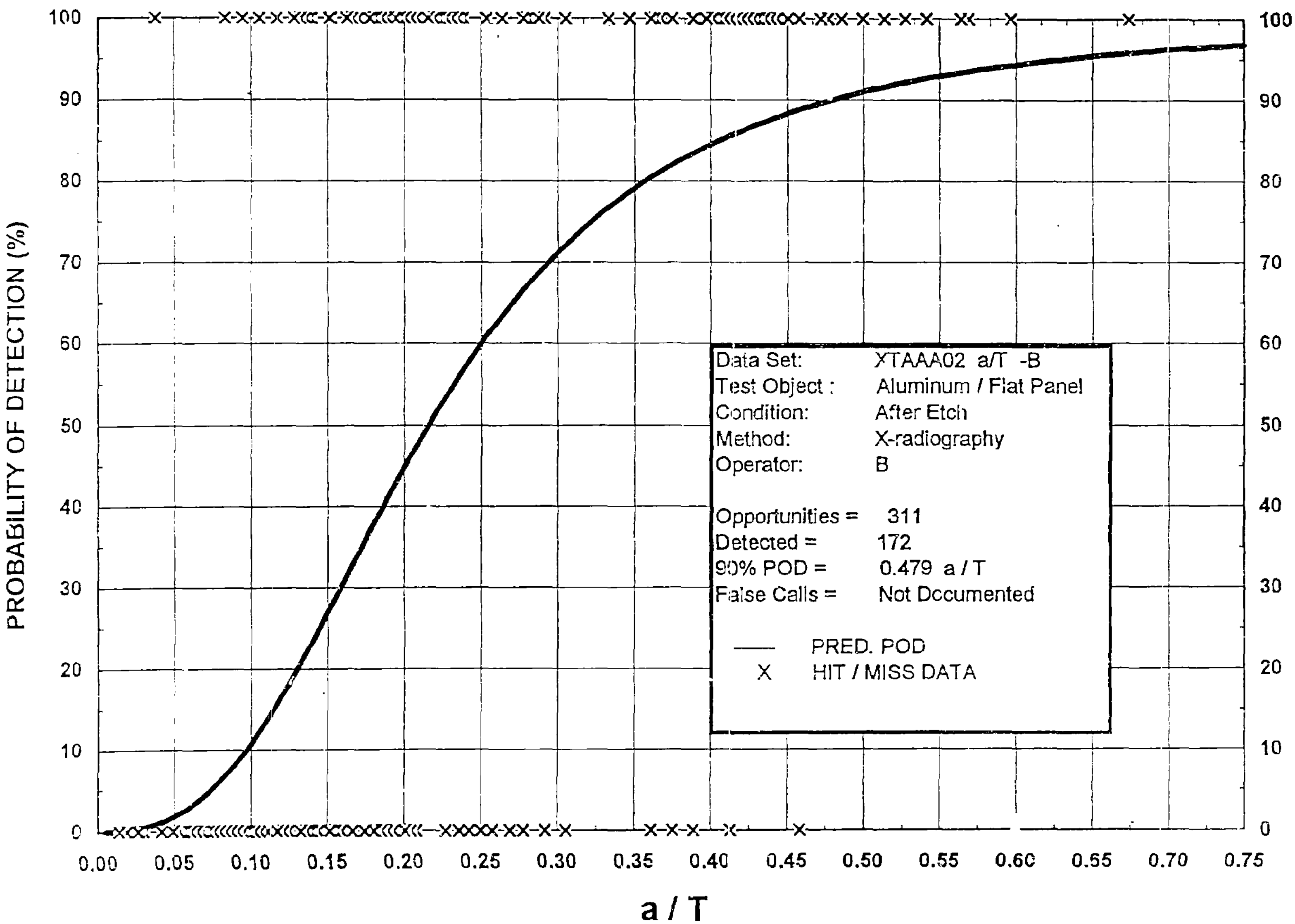
XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAA01 a / T -C
FLAT PLATE ALUNIMUM - OPERATOR C



XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAA02 a / T -A
FLAT PLATE ALUMINUM - OPERATOR A

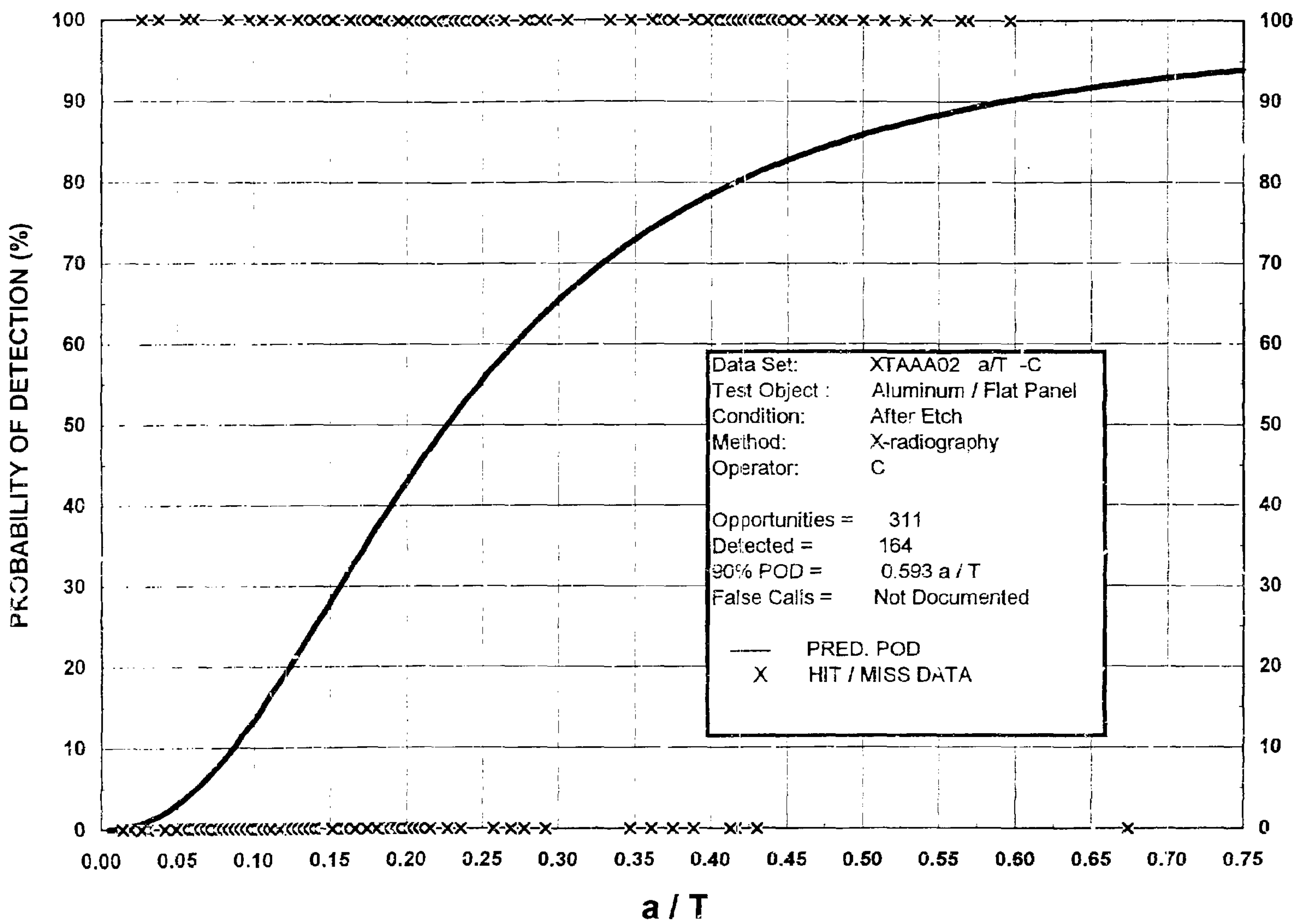


XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO

6/95

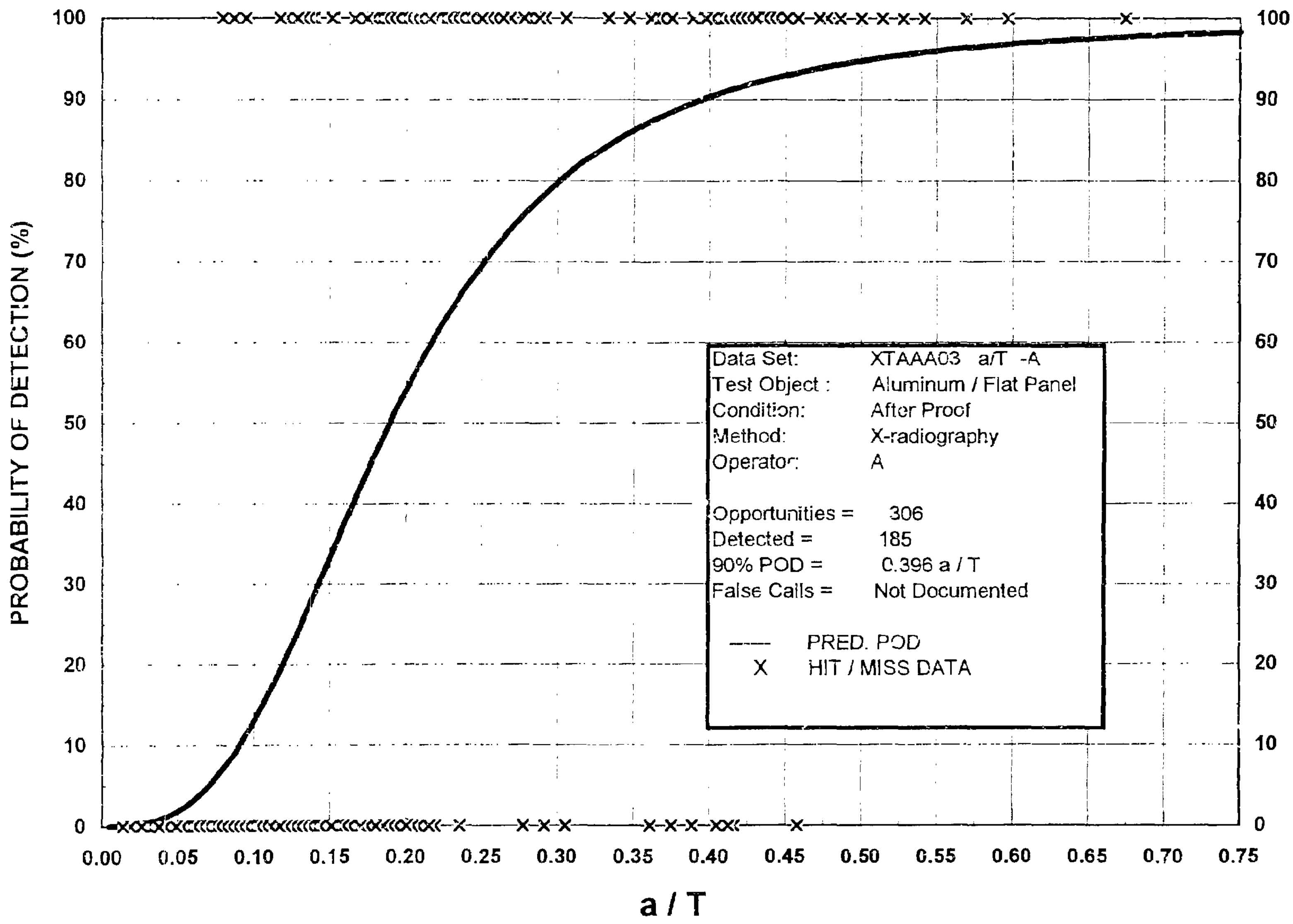
XTAAA02 a / T -B

FLAT PLATE ALUMINUM - OPERATOR B



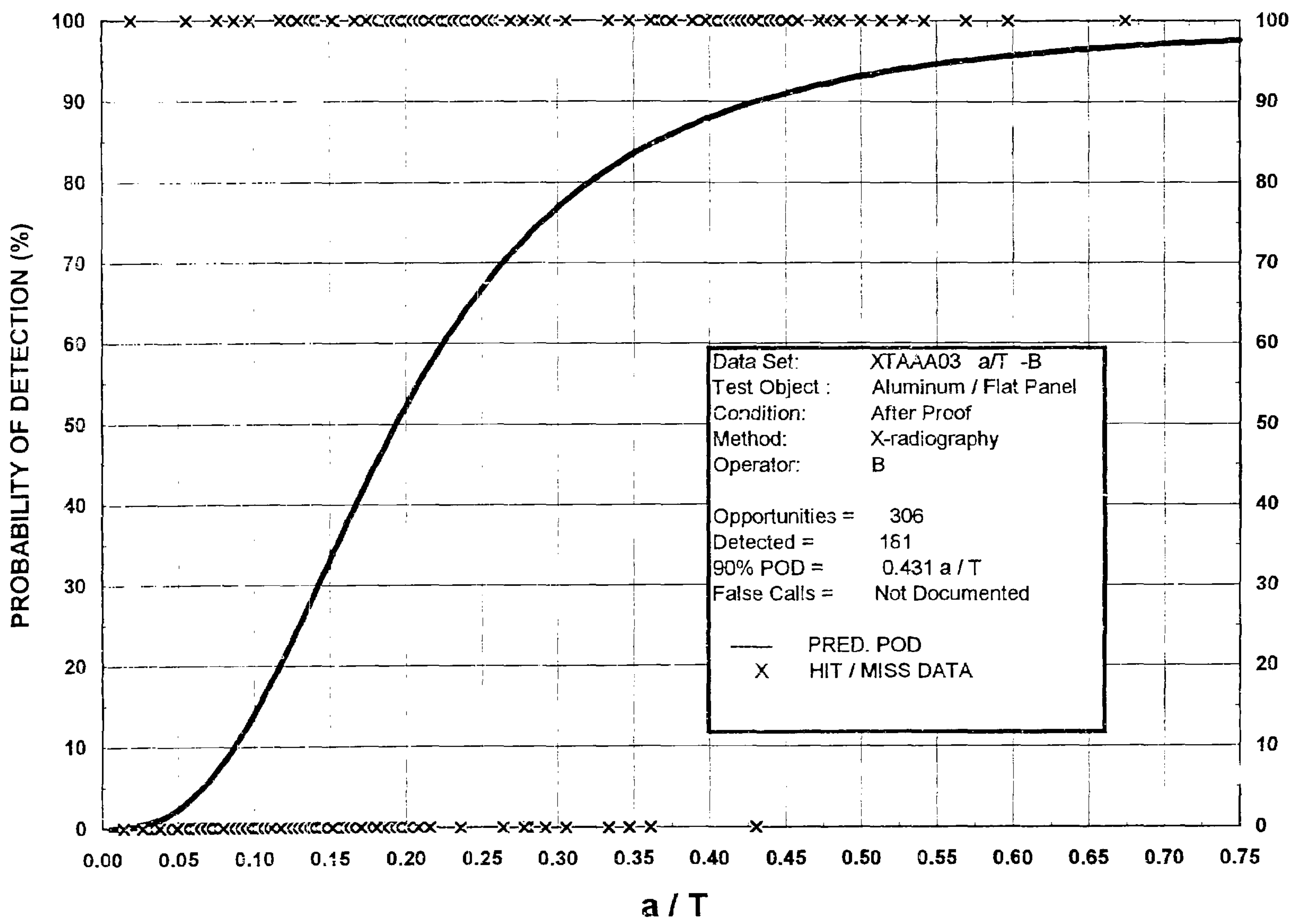
XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAA02 a / T -C
FLAT PLATE ALUMINUM - OPERATOR C



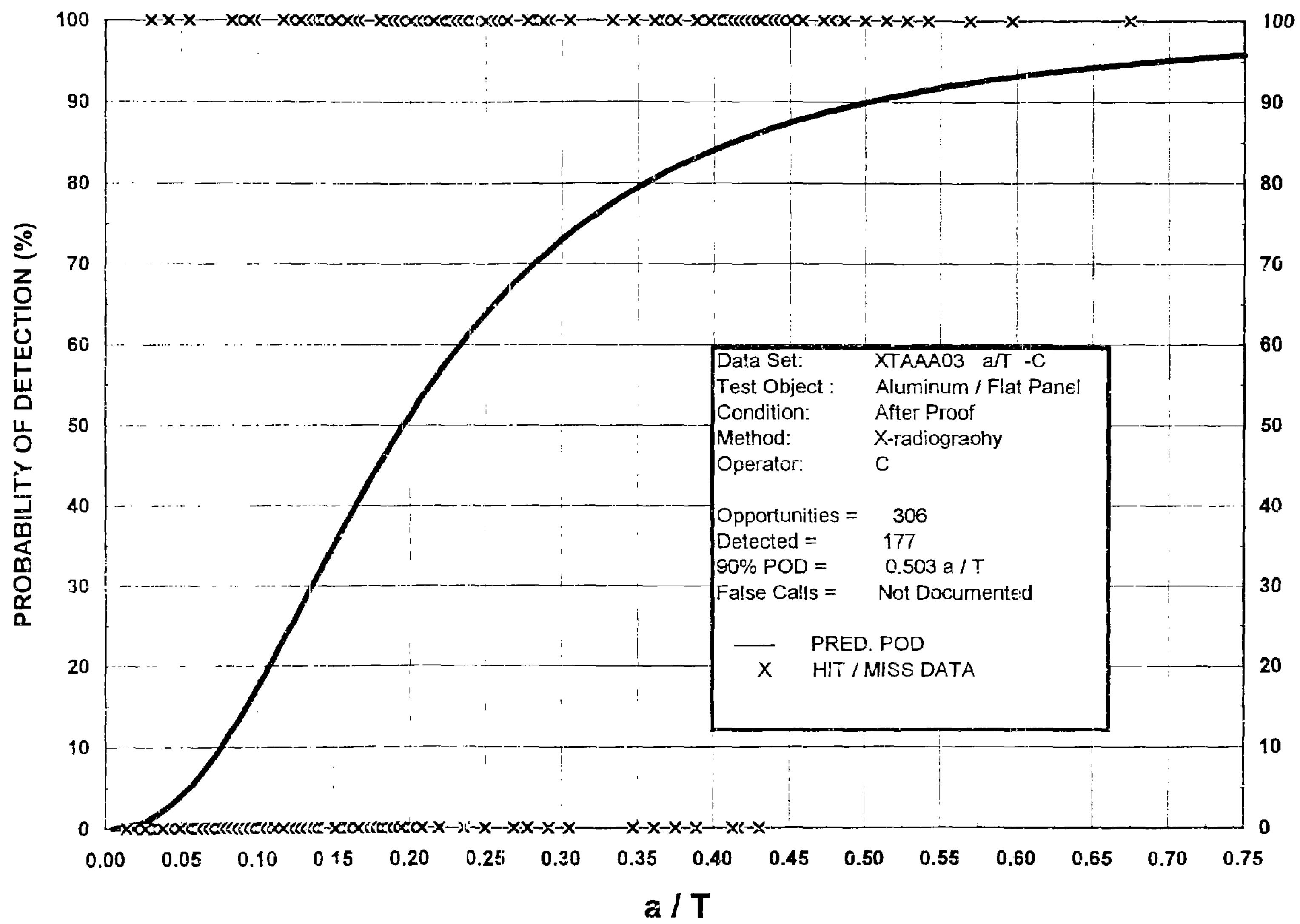
XT - 01 (1)C, CRACK DEPTH THE THICKNESS
6/95

XTAAA03 a / T -A
FLAT PLATE ALUMINUM - OPERATOR A



XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAA03 a / T -B
FLAT PLATE ALUMINUM - OPERATOR B

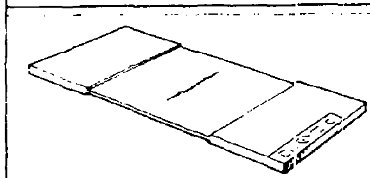


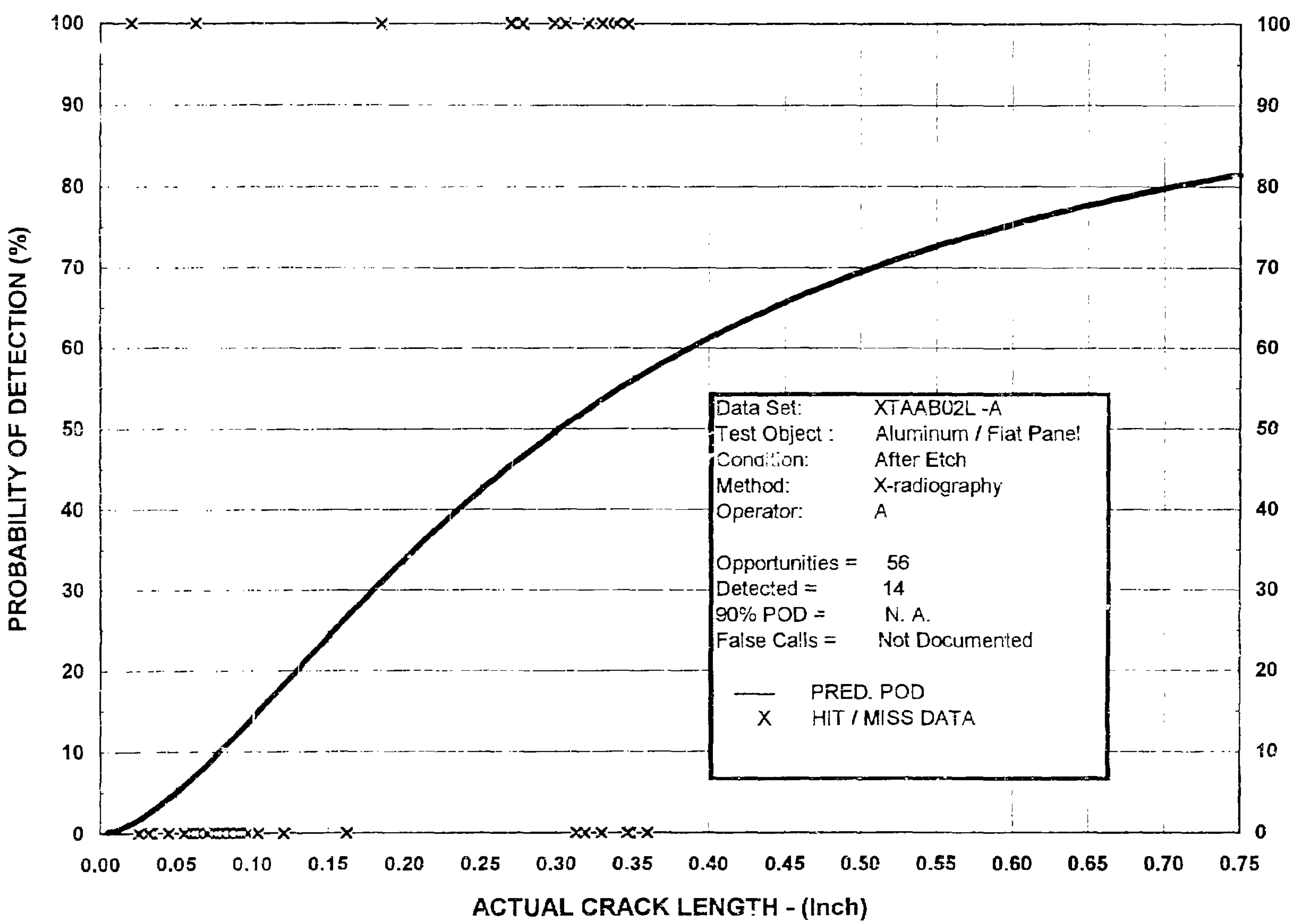
XT - 01 (1)C, CRACK DEPTH TO THICKNESS RATIO

6/95

XTAAA03 a / T -C

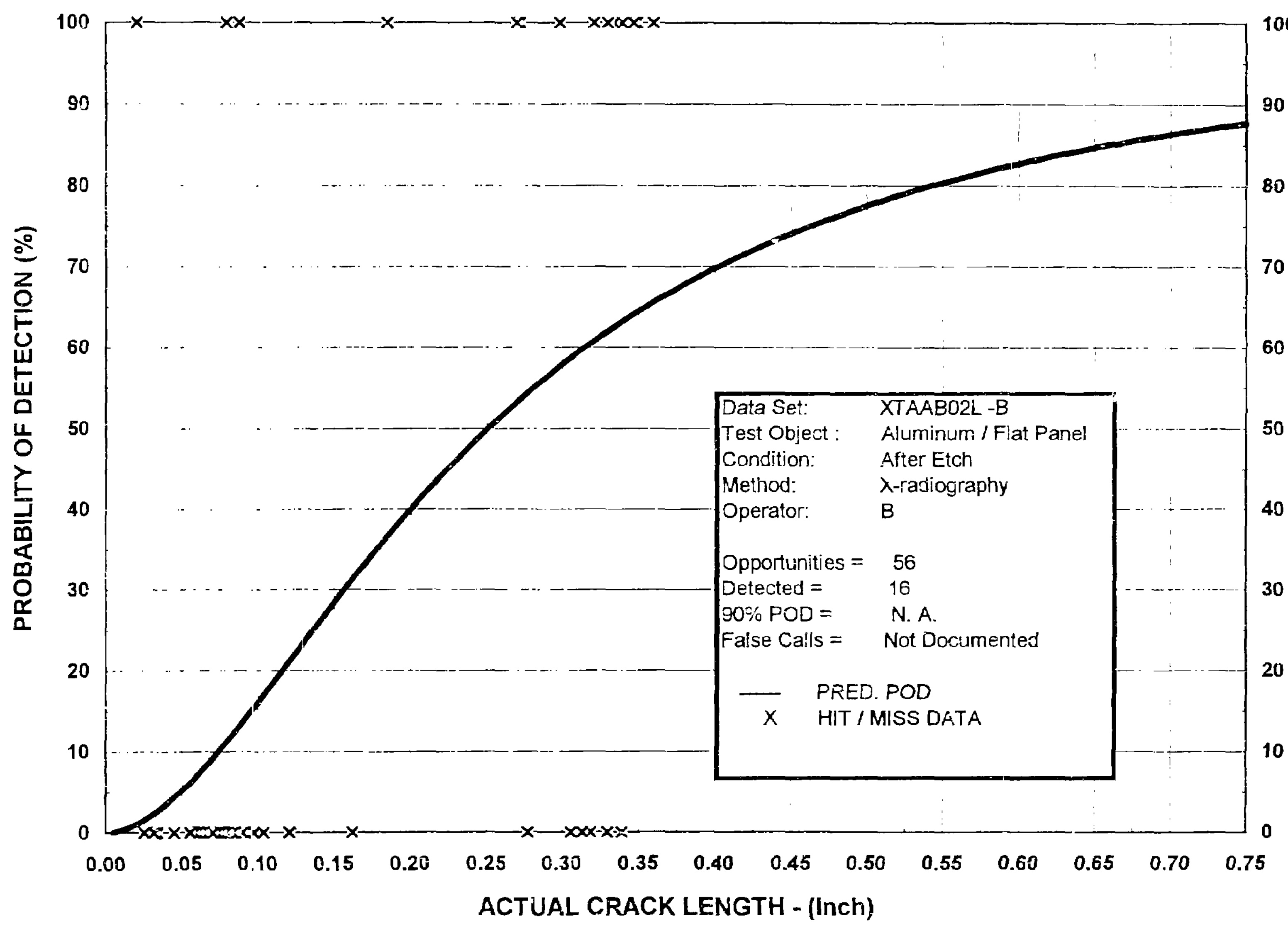
FLAT PLATE ALUMINUM - OPERATOR C

XT - 02 (1)A CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides (General Dynamics Panels)
NDE PROCEDURE:	X-radiography, Kodak Type M film/ automatic film processing / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.085 and 0.220 inch nominal
TEST OBJECT CONDITION:	"After Etch"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Automatic film processing / Manual Recording
DATA SET IDENTIFIER:	XTAAB02L-A,B,C Separated into 0.085 in. and 0.220 in. thicknesses
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	XTAAB02L-A,B,C; 56 in the 0.085 in. and 60 opportunities in the 0.220 in. thickness.
DETECTED:	0.085 in., A=14,B=16,C=19; 0.220 in.-A=28,B=24,C=31
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel. Ward D., Paul H. Todd Jr , Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner. NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**
	*90% POD by Length in the 0.085 in. thickness; in the 0.220 thickness*
	A= N.A A= N.A.
	B= N.A. B= N.A.
	C= 0.502 in. C= N.A.



XT - 02 (1)A, CRACK LENGTH
6/95

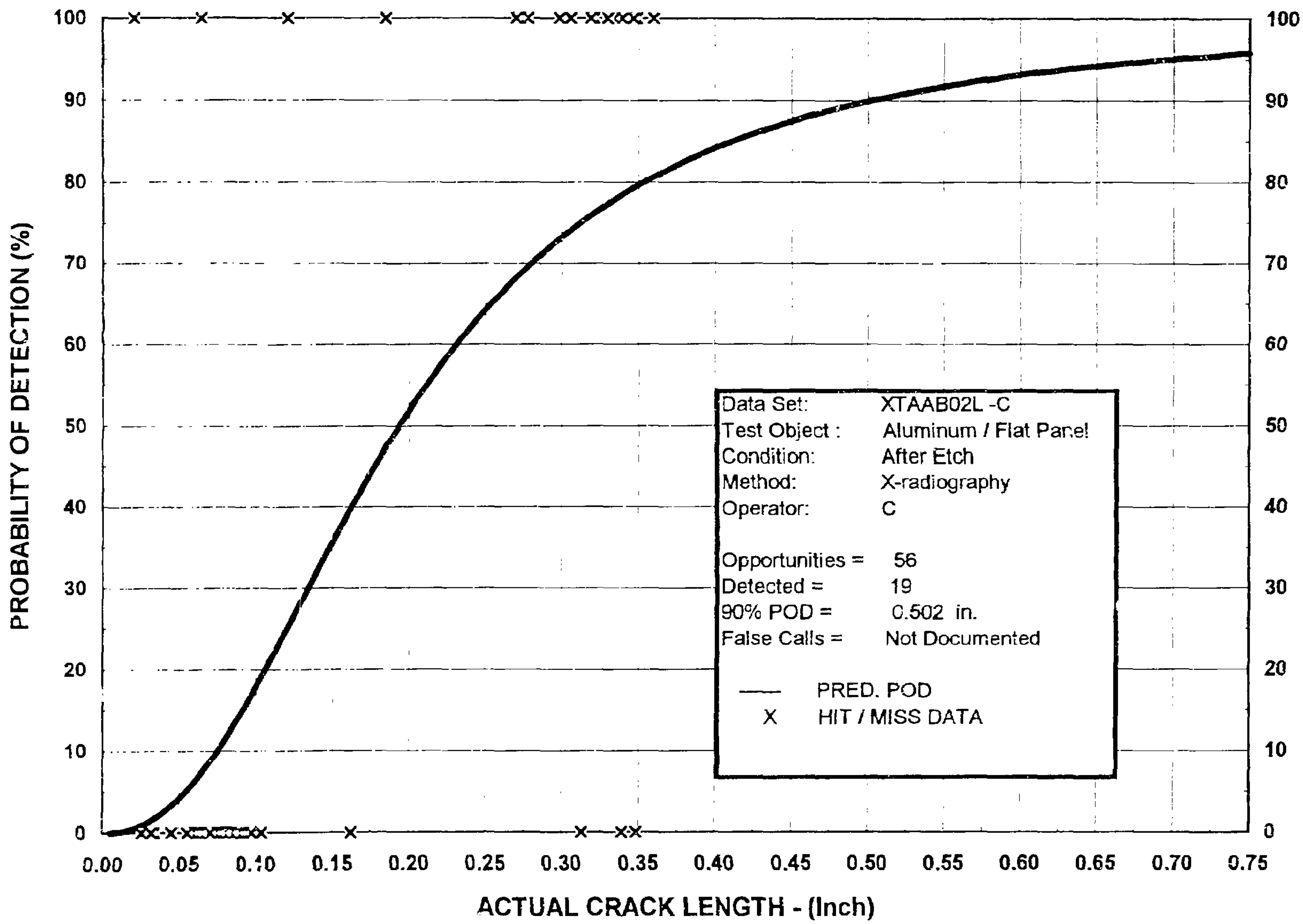
0.085 Inch Nominal Panel Thickness - XTAAB02L-A



XT - 02 (1)A, CRACK LENGTH

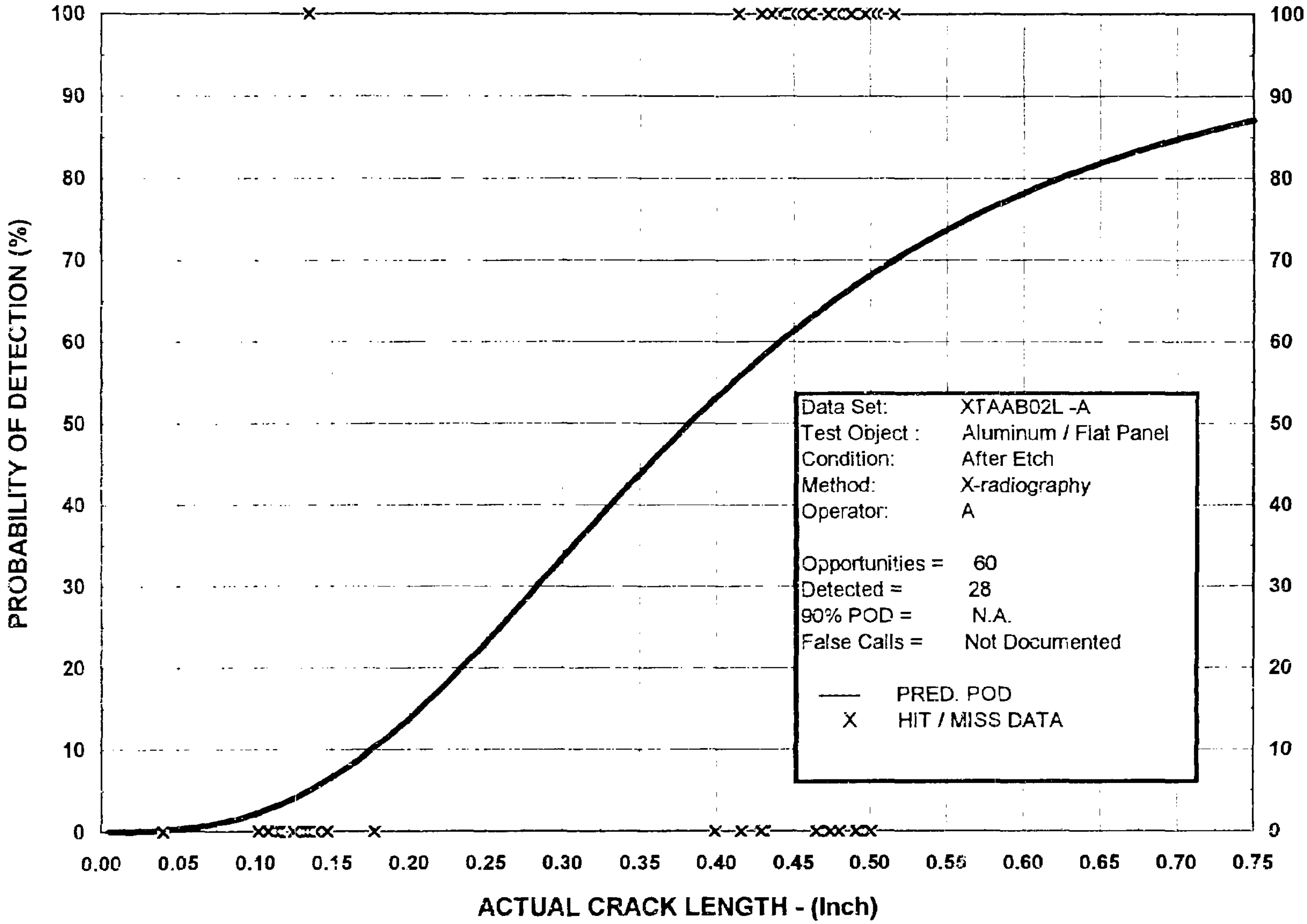
6/95

0.085 Inch Nominal Panel Thickness - XTAAB02L-B



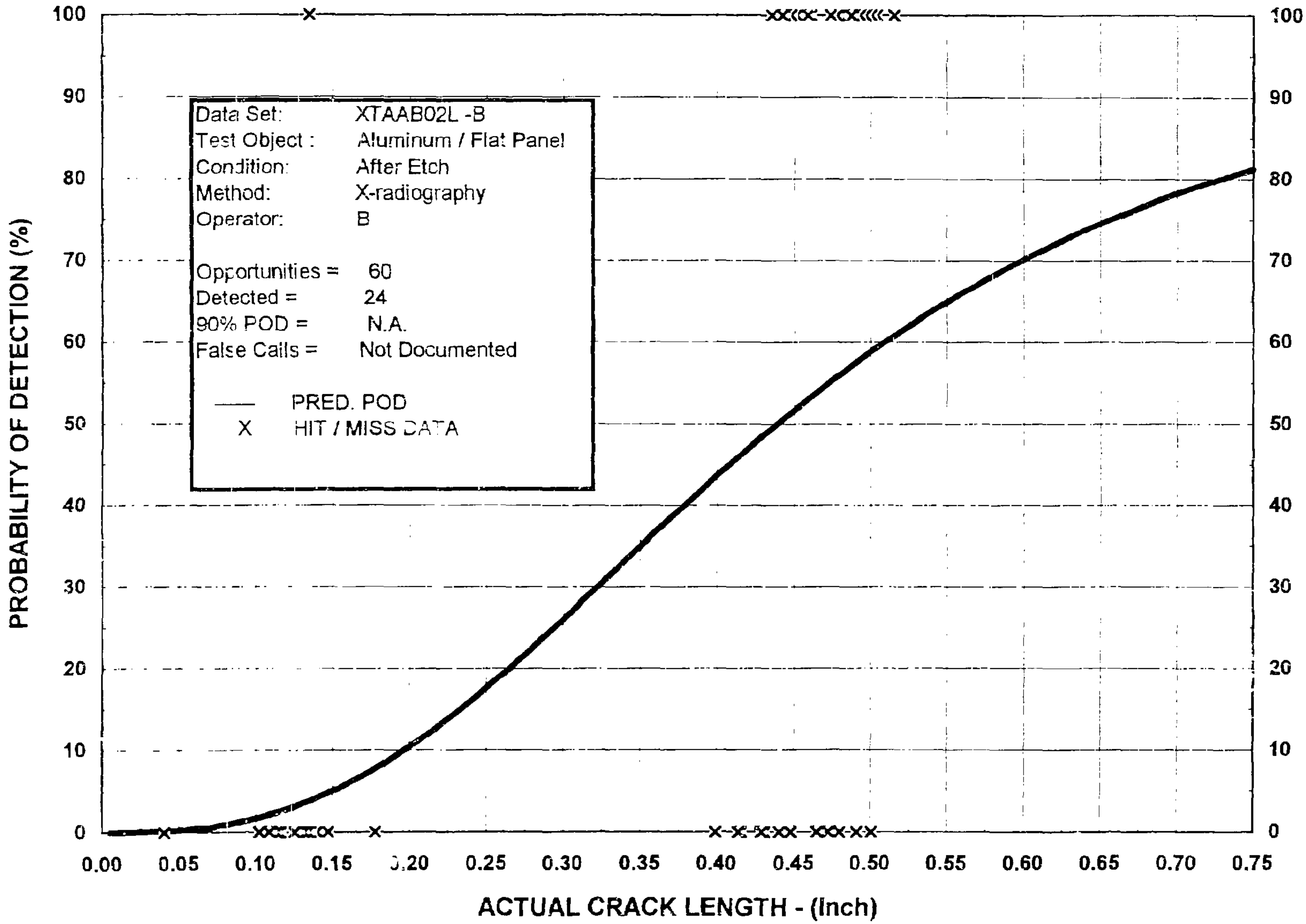
XT - 02 (1)A, CRACK LENGTH
6/95

0.085 Inch Nominal Panel Thickness - XTAAB02L-C



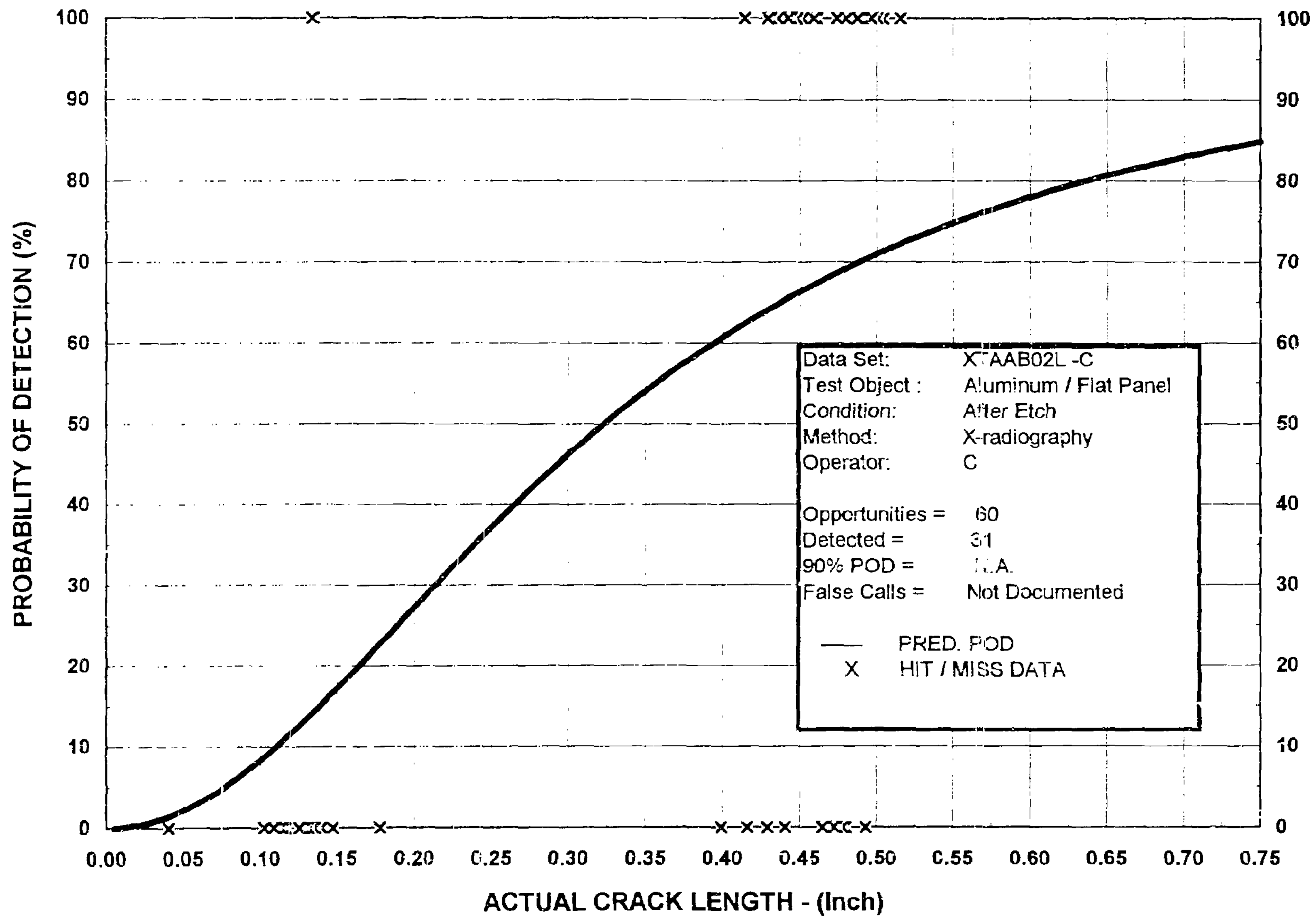
XT - 02 (1)A, CRACK LENGTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAB02L-A



XT - 02 (1)A, CRACK LENGTH
6/95

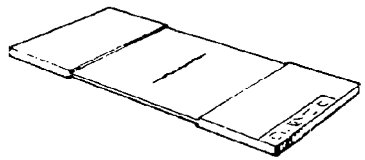
0.220 Inch Nominal Panel Thickness - XTAAB02L-B

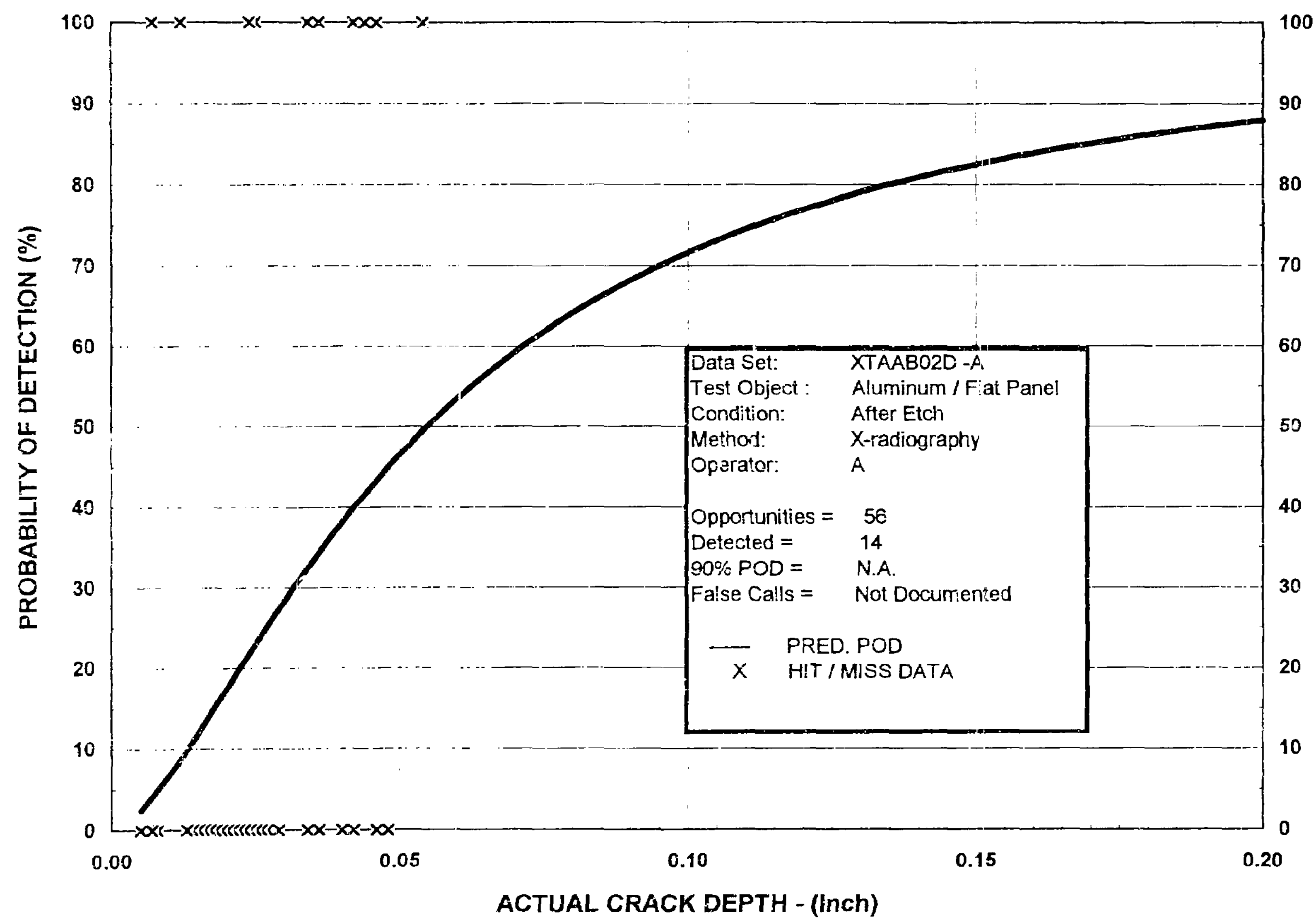


XT - 02 (1)A, CRACK LENGTH

6/35

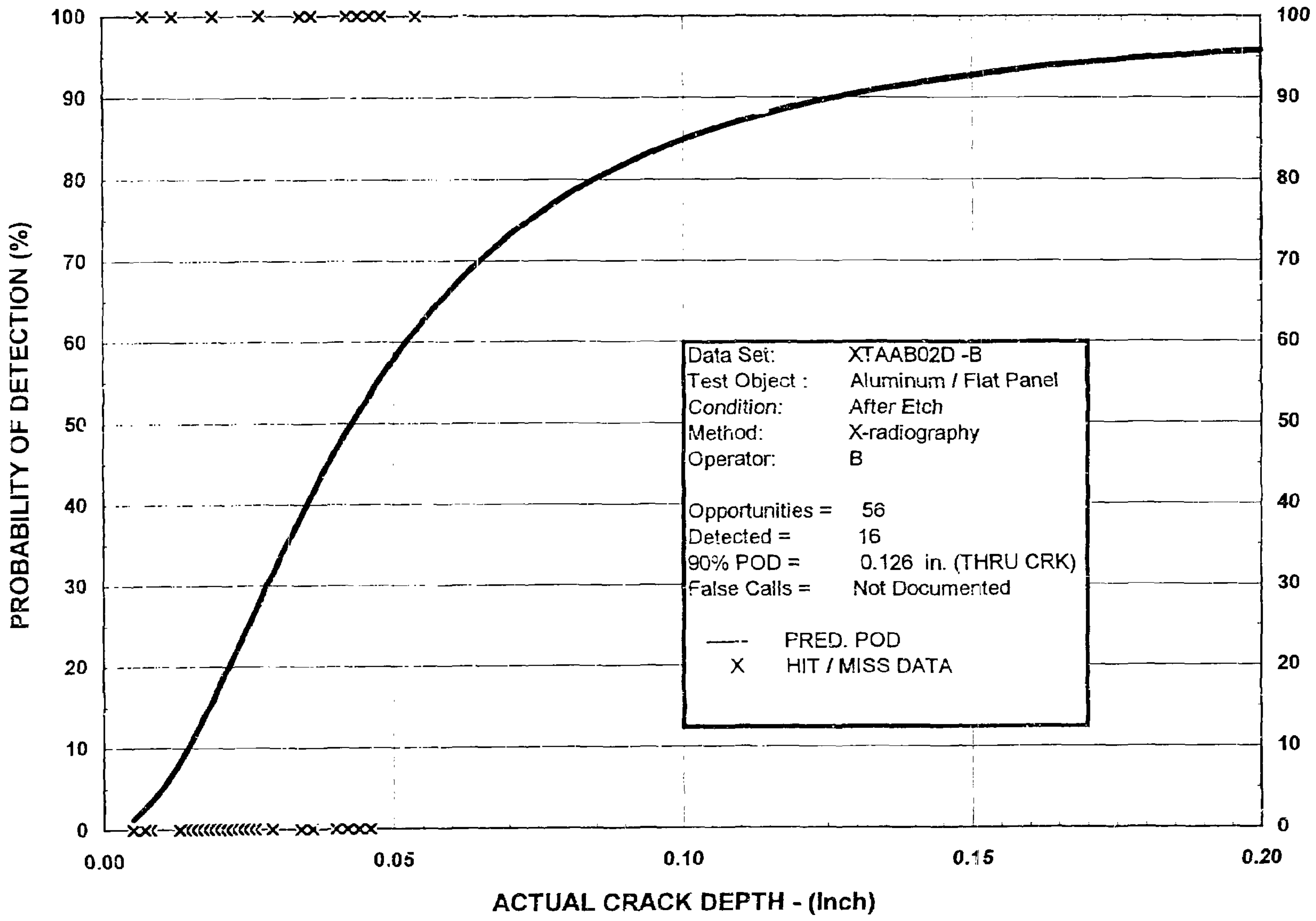
0.220 Inch Nominal Panel Thickness - XTAAB02L-C

XT - 02 (1)B CRACK DEPTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides (General Dynamics Panels)
NDE PROCEDURE:	X-radiography, Kodak Type M film/ automatic film processing / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.085 and 0.220 inch nominal
TEST OBJECT CONDITION:	"After Etch"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Automatic film processing / Manual Recording
DATA SET IDENTIFIER:	XTAABC2D-A,B,C Separated into 0.085 in. and 0.220 in. thicknesses
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	XTAABC2D-A,B,C; 56 in the 0.085 in. and 60 opportunities in the 0.220 in. thickness.
DETECTED:	0.085 in., A=14,B=16,C=19; 0.220 in.-A=28,B=24,C=31
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**
	90% POD by crack Depth in the 0.085 in. thickness; in the 0.220 in. thickness
	A= N.A. A= 0.137 in.
	B= 0.126 in. B= 0.136 in.
	C= 0.091 in. C= 0.148 in.



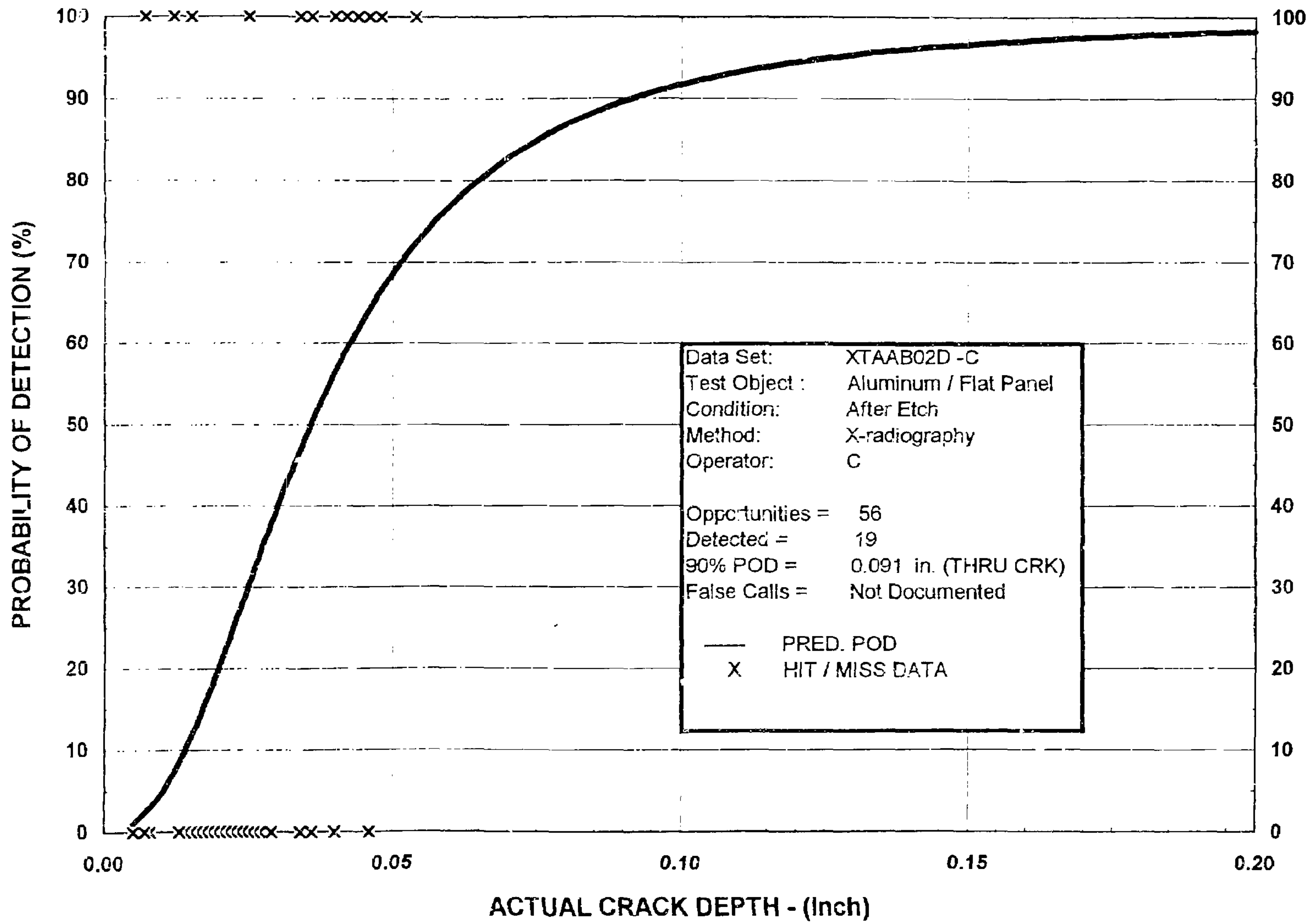
XT - 02 (1)B, CRACK DEPTH
6/95

0.085 Inch Nominal Panel Thickness - XTAAB02D-A



XT - 02 (1)B, CRACK DEPTH
6/95

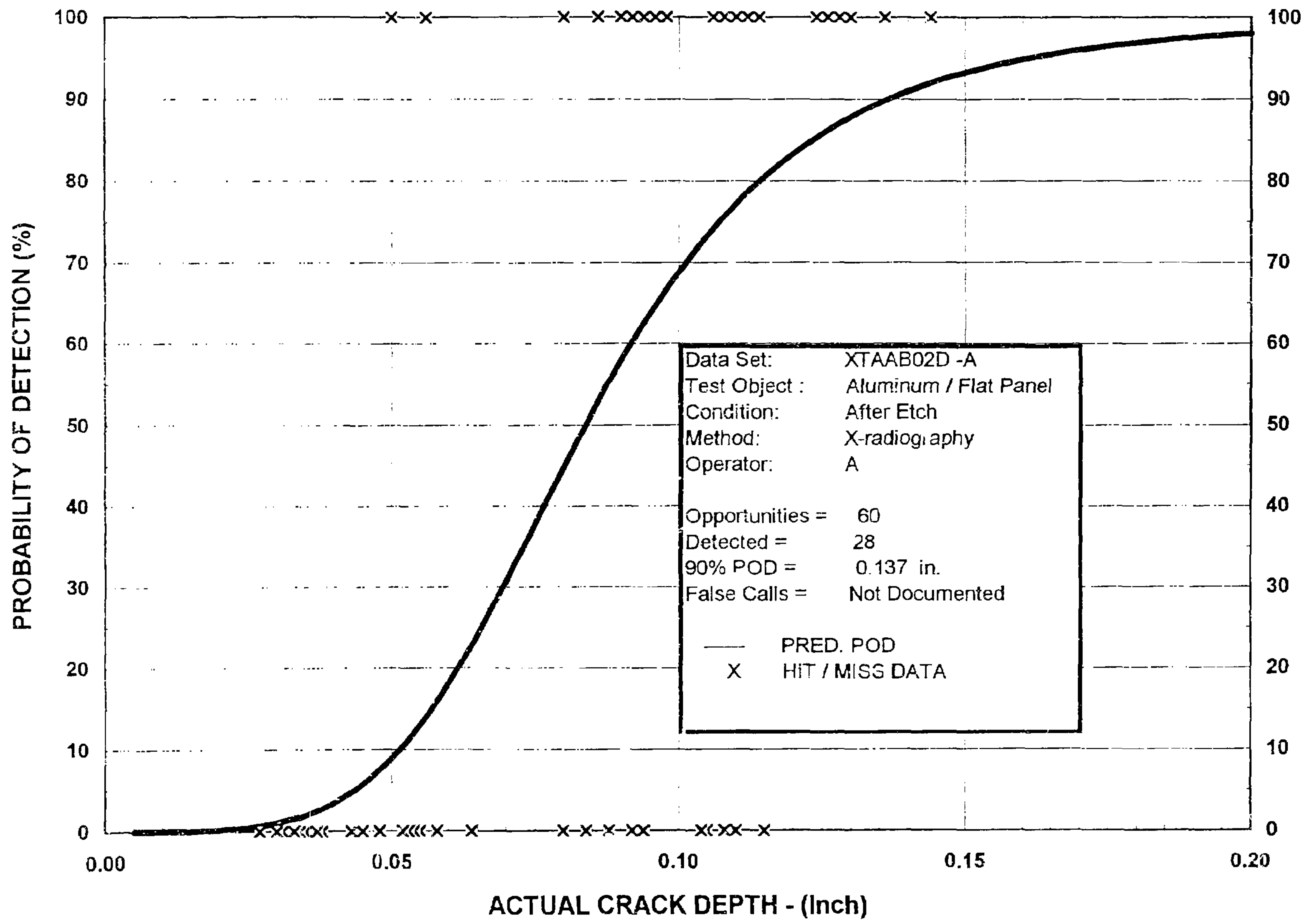
0.085 Inch Nominal Panel Thickness - XTAAB02D-B



XT - 02 (1)B, CRACK DEPTH

6/95

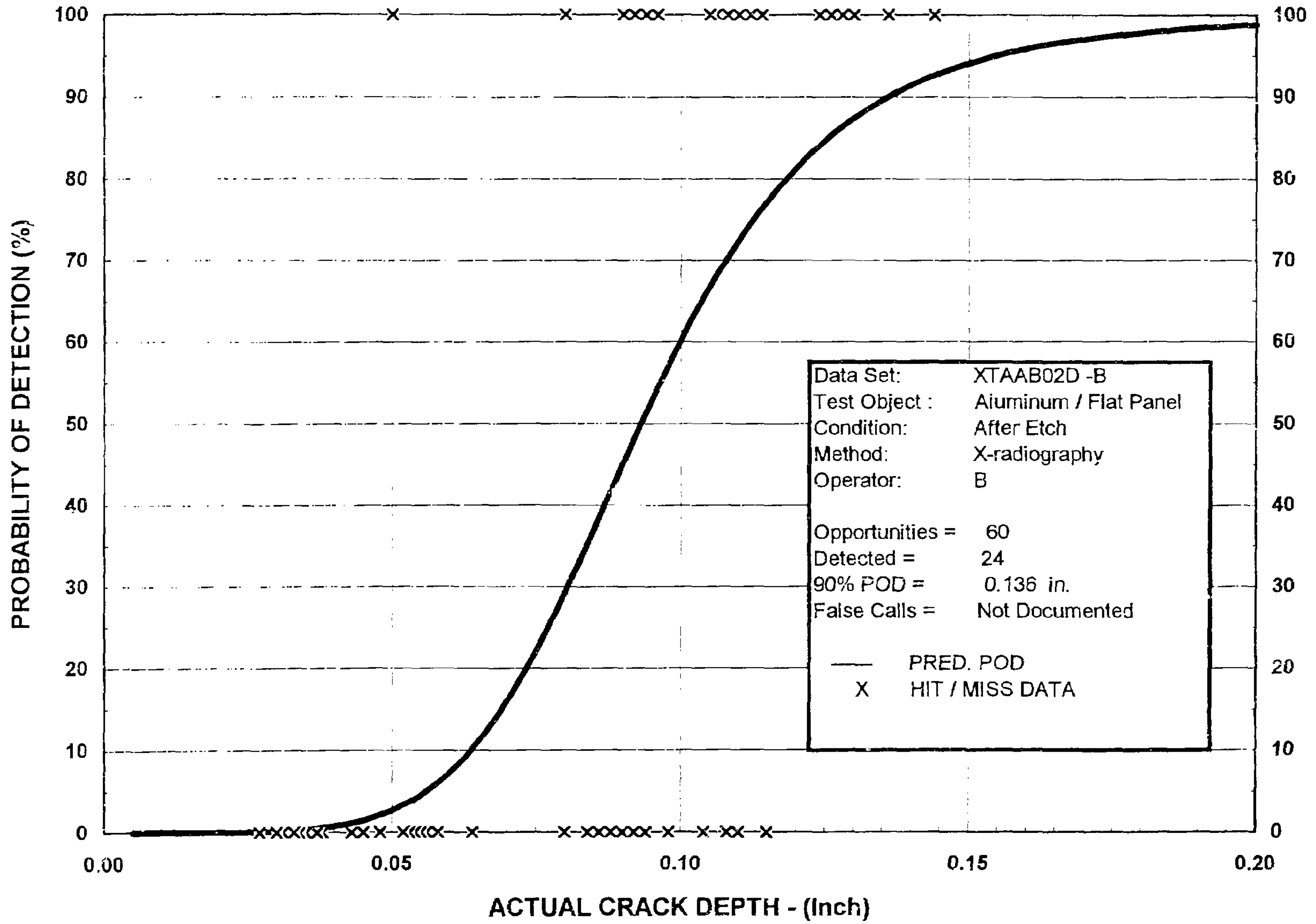
0.085 Inch Nominal Panel Thickness - XTAAB02D-C



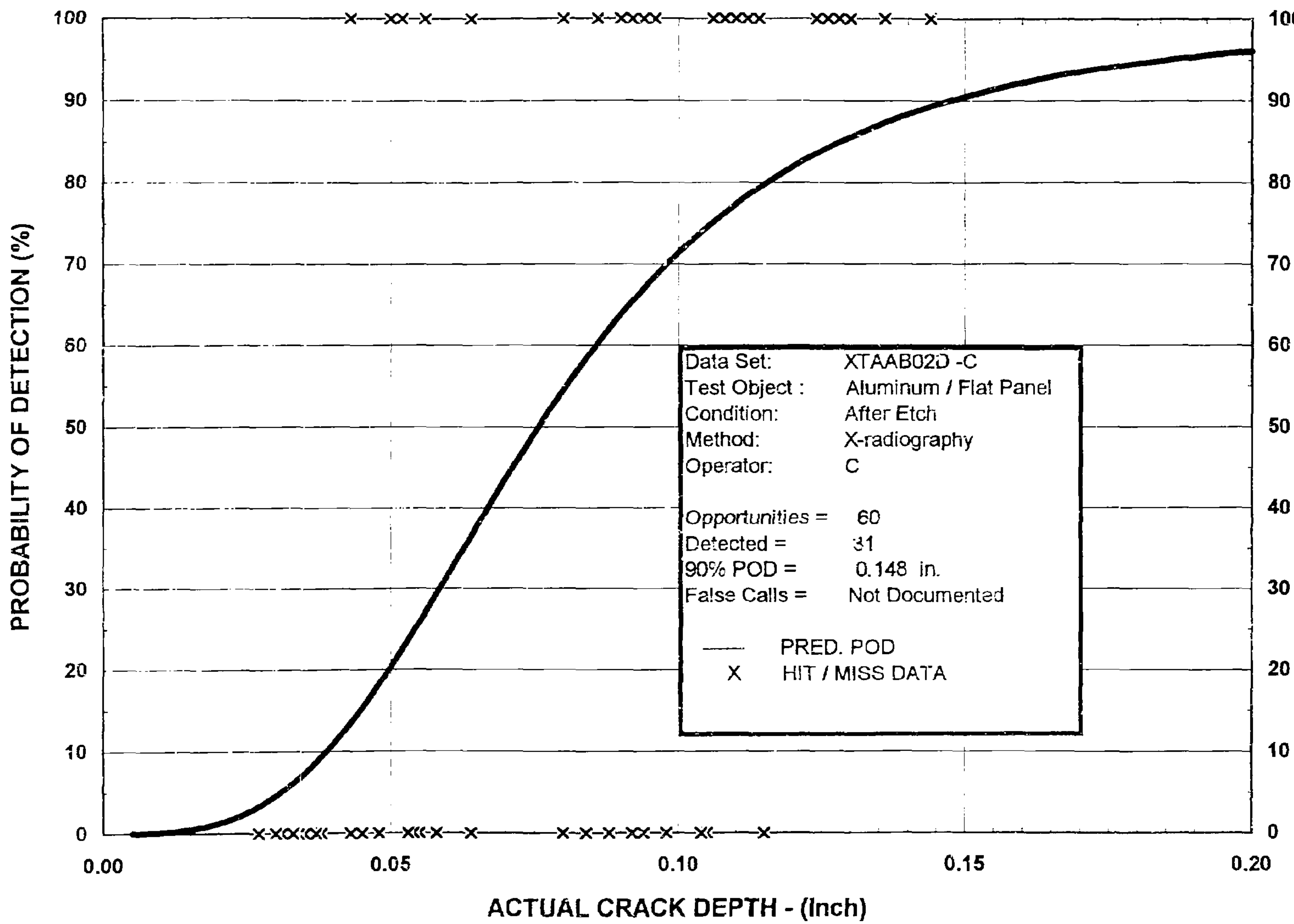
XT - 02 (1)B, CRACK DEPTH

6/95

0.220 Inch Nominal Panel Thickness - XTAAB02D-A



0.220 Inch Nominal Panel Thickness - XTAAB02D-B



XT - 02 (1)B, CRACK DEPTH
6/95

0.220 Inch Nominal Panel Thickness - XTAAB02D-C

XT - 02 (1)C A / T	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides (General Dynamics Panels)
NDE PROCEDURE:	X-radiography, Kodak Type M film/ automatic film processing / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.085 and 0.220 inch nominal
TEST OBJECT CONDITION:	"After Etch"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Automatic film processing / Manual Recording
DATA SET IDENTIFIER:	XTAAB02 a/T -A,B,C (Combined data from 0.085 in. and 0.220 in. panel thicknesses
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	XTAAB02 a/T = 116 opportunities.
DETECTED:	XTAAB02 a/T. A=42,B=40,C=50
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace. Denver, Colorado
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	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
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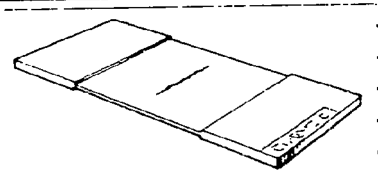
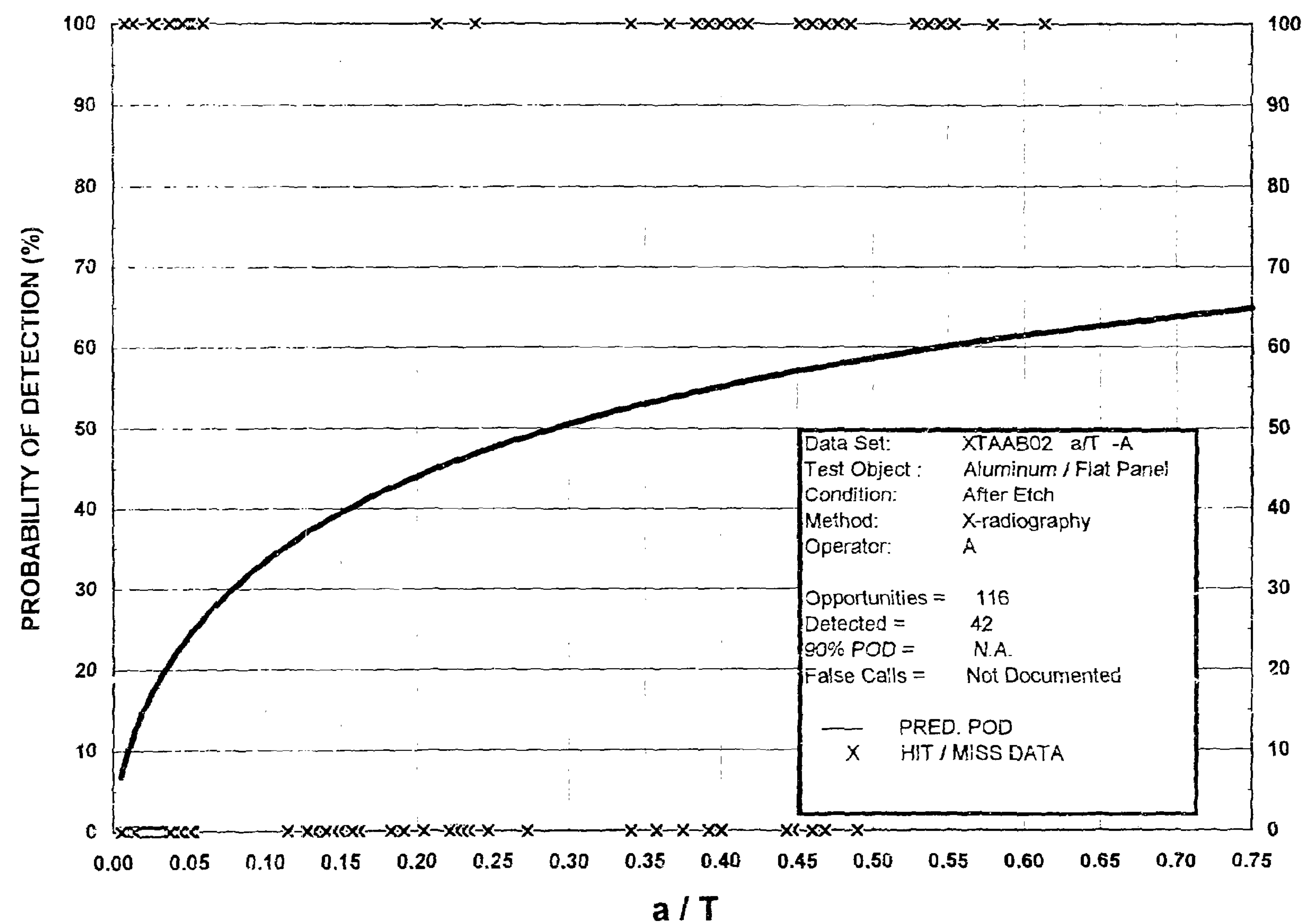
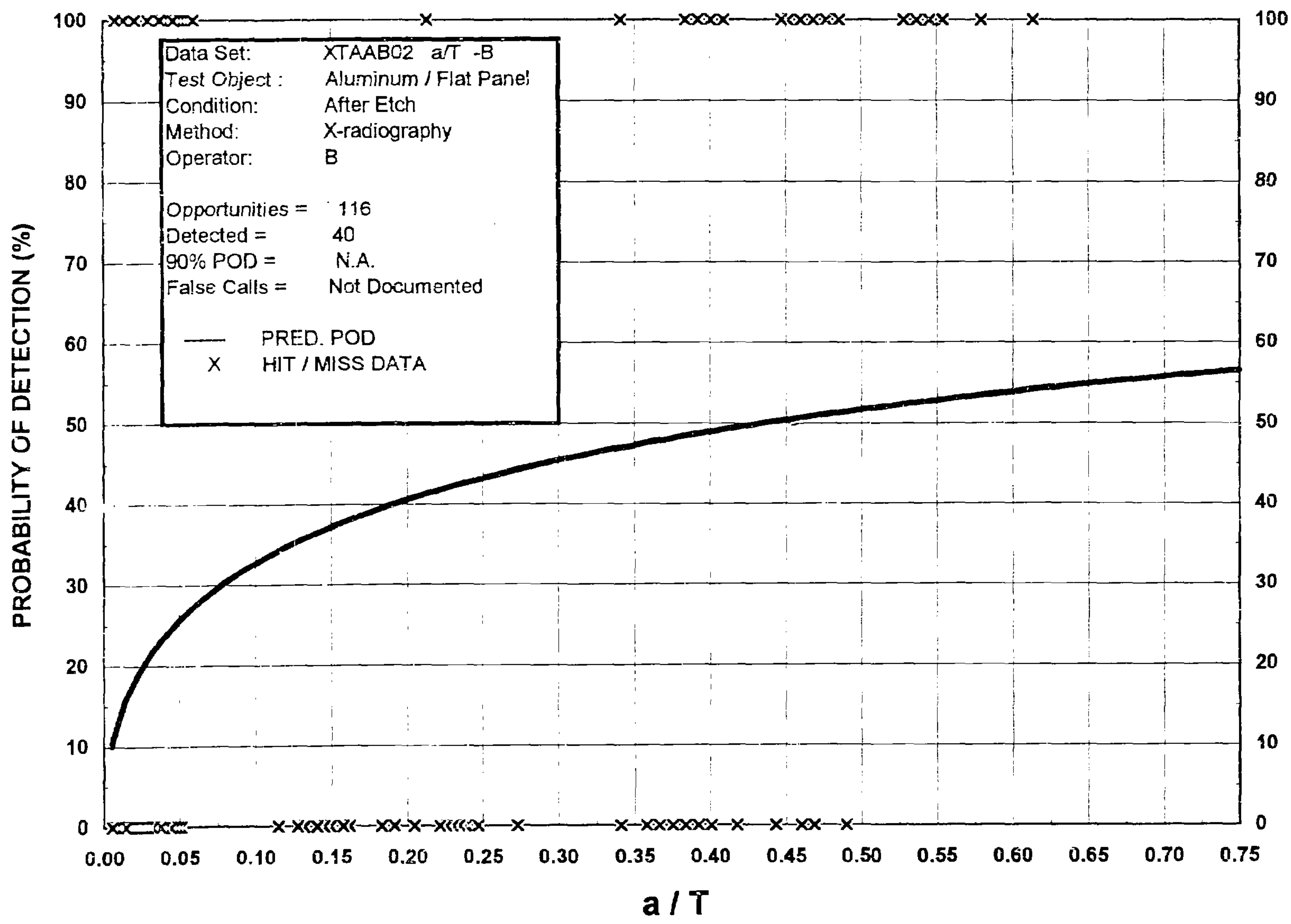
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations. **THIS DATA FROM THE GENERAL DYNAMICS PANELS**
	90% POD by crack depth to thickness ratio
	A= N.A.
	B= N.A.
	C= N.A.

X-RADIOGRAPHY BY CRACK DEPTH TO THICKNESS RATIO
ALUMINUM - FLAT PANELS



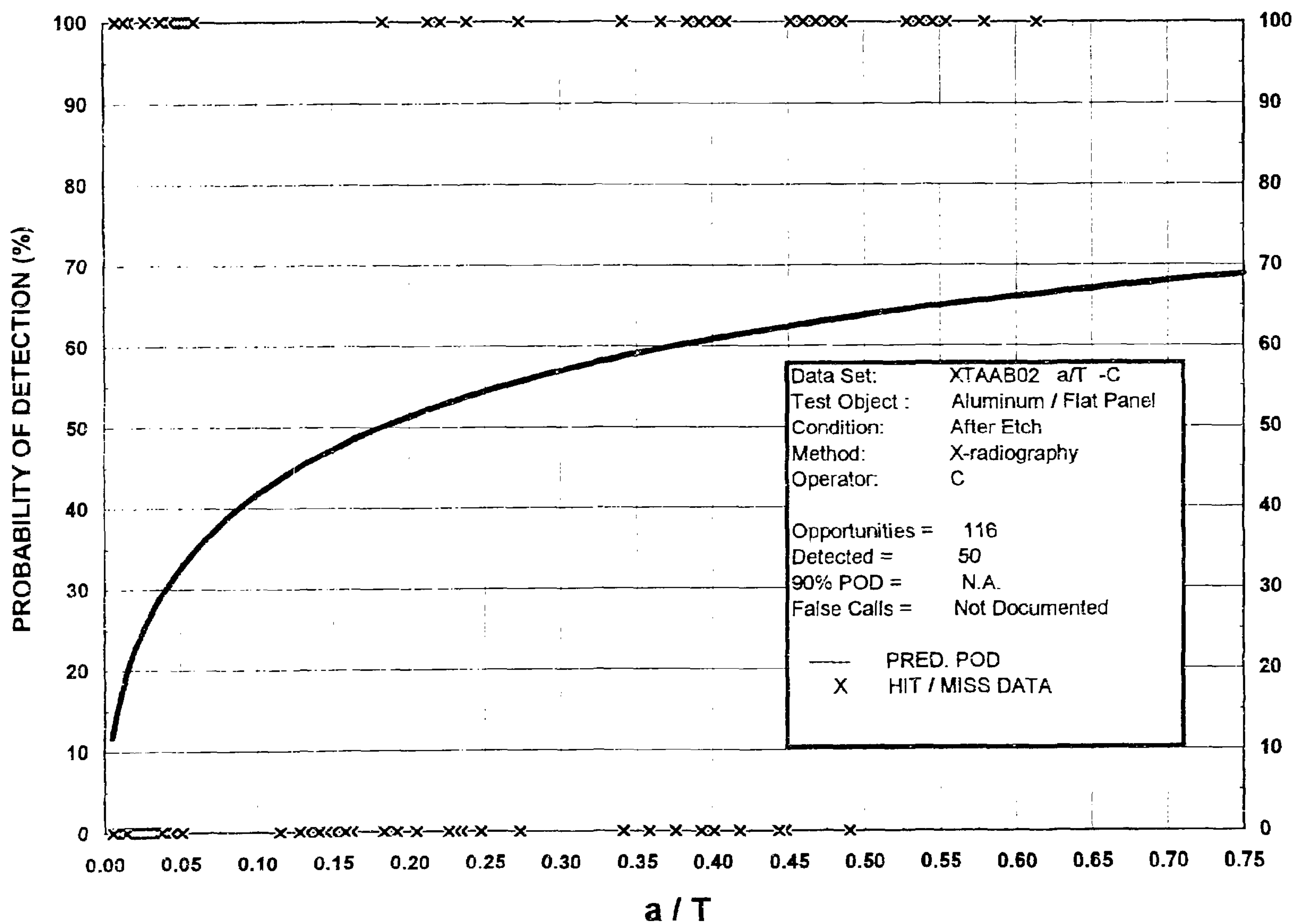
XT - 02 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAB02 a / T -A
FLAT PLATE ALUMINUM - OPERATOR A



XT - 02 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

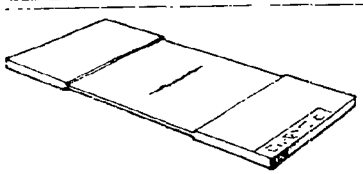
XTAAB02 a / T -B
FLAT PLATE ALUMINUM - OPERATOR B



XT - 02 (1)C, CRACK DEPTH TO THICKNESS RATIO
6/95

XTAAB02 a / T
FLAT PLATE ALUMINUM - OPERATO

XT 03 (2)A CRACK LENGTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches. cracks on both sides
NDE PROCEDURE:	X-radiography. Kodak Type M film/ automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Titanium plate - 6Al4V
TEST OBJECT THICKNESS:	0.085 and 0.225 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined"; -03,"After Proof"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Reading / Manual Recording
DATA SET IDENTIFIER:	XTAA01L - A,B,C Separated into 0.065 in. and 0.225 in. thicknesses
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	61 (0.065 in.) and 74 (0.225 in.) Cracks (All cracks not inspected by all operators.
DETECTED:	(0.065 in.)01L. A=29 B=25, C=29; 03L,A=44.B=43,C=41;(0.225 in.)01L,A=18,B=17,C=15;03L,A=41,B=39,C=36
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria.
	Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	90% POD by crack length

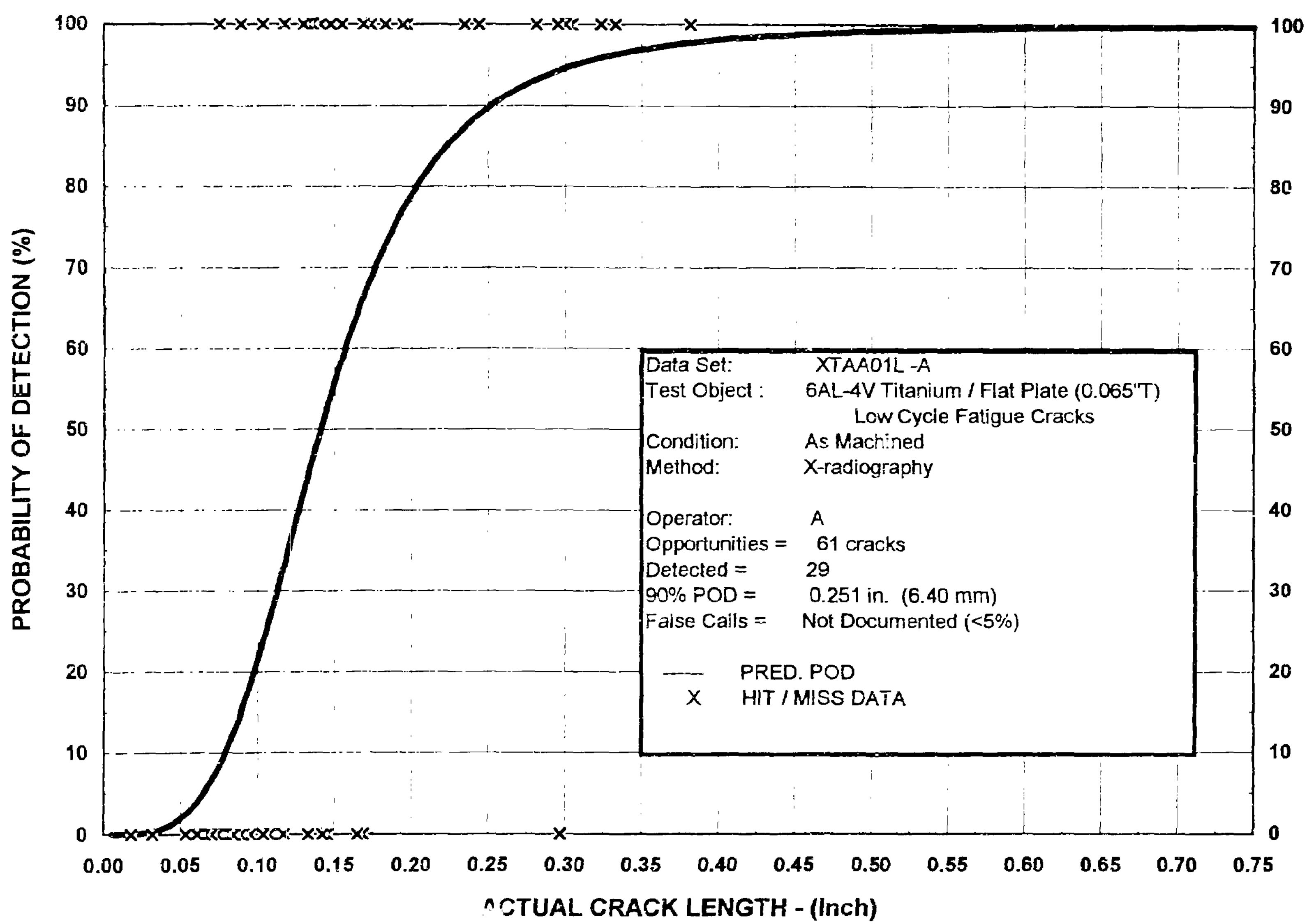


(0.065 in.) -01 ;	- 03;	(0.225 in.) -01	-03
A= 0.251 in.	A= N.A.	A= N.A.	A= 0.601 in.
B= 0.288 in.	B= N.A.	B= N.A.	B= 0.363 in.
C= 0.220 in..	C= 0.729 in.	C= N.A.	C= N.A.

XT - 03 (2)A, CRACK LENGTH FOR TWO DIFFERENT THICKNESSES

6/95

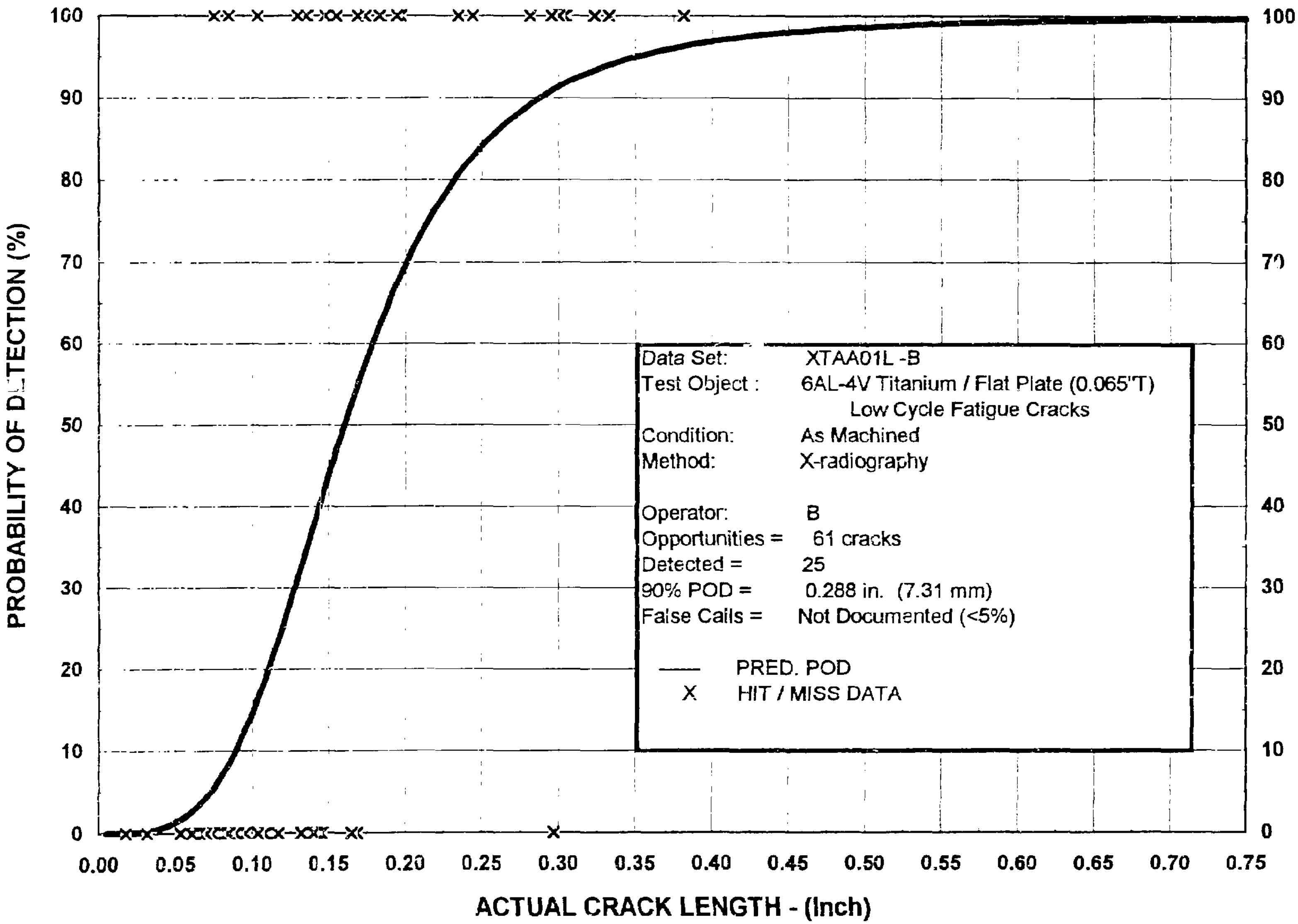
X-RADIOGRAPHY
TITANIUM PANELS



XT - 03 (2)A, TITANIUM FLAT PLATE

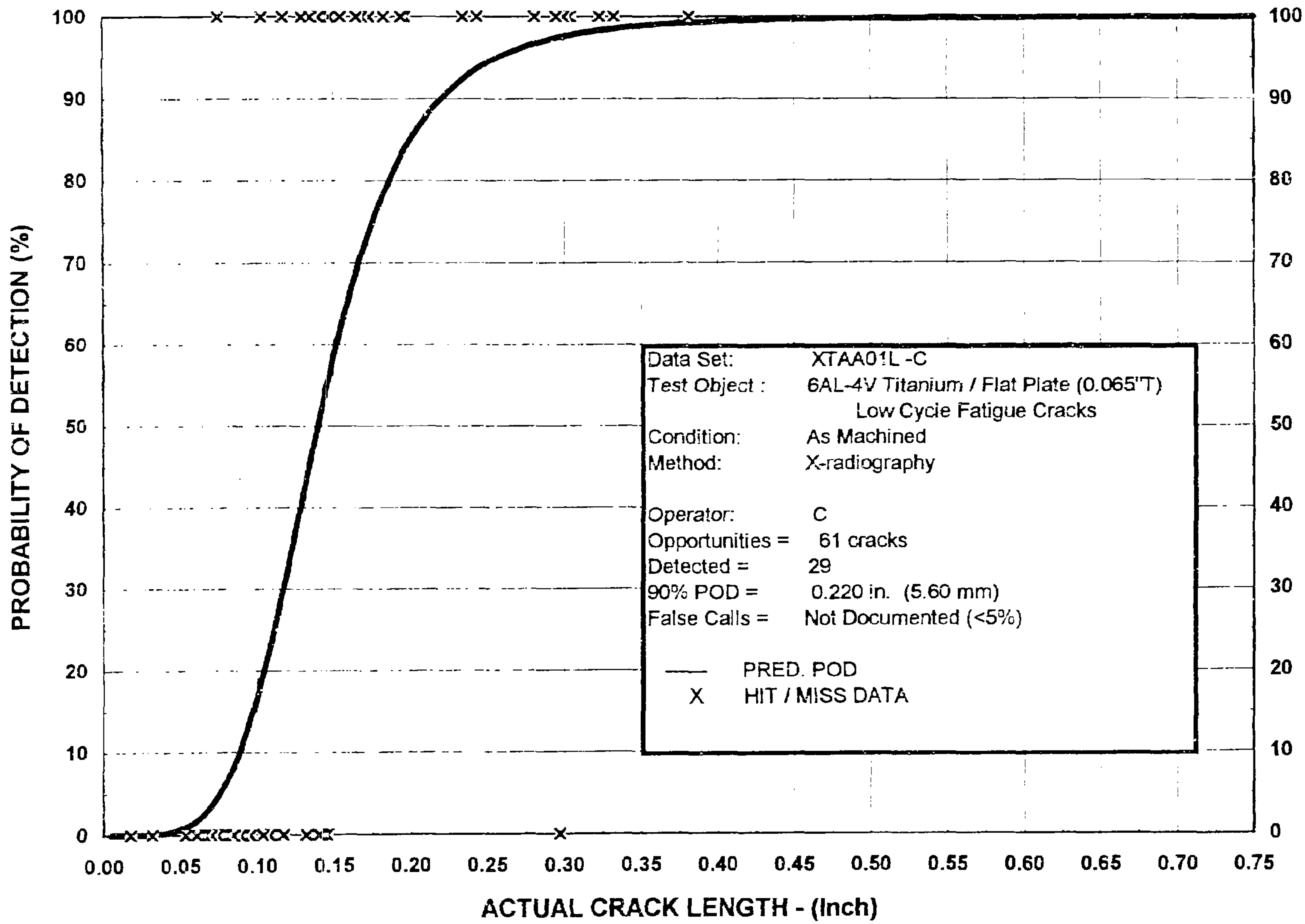
06/95

XTAA01L-A
(0.065 " T)



XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

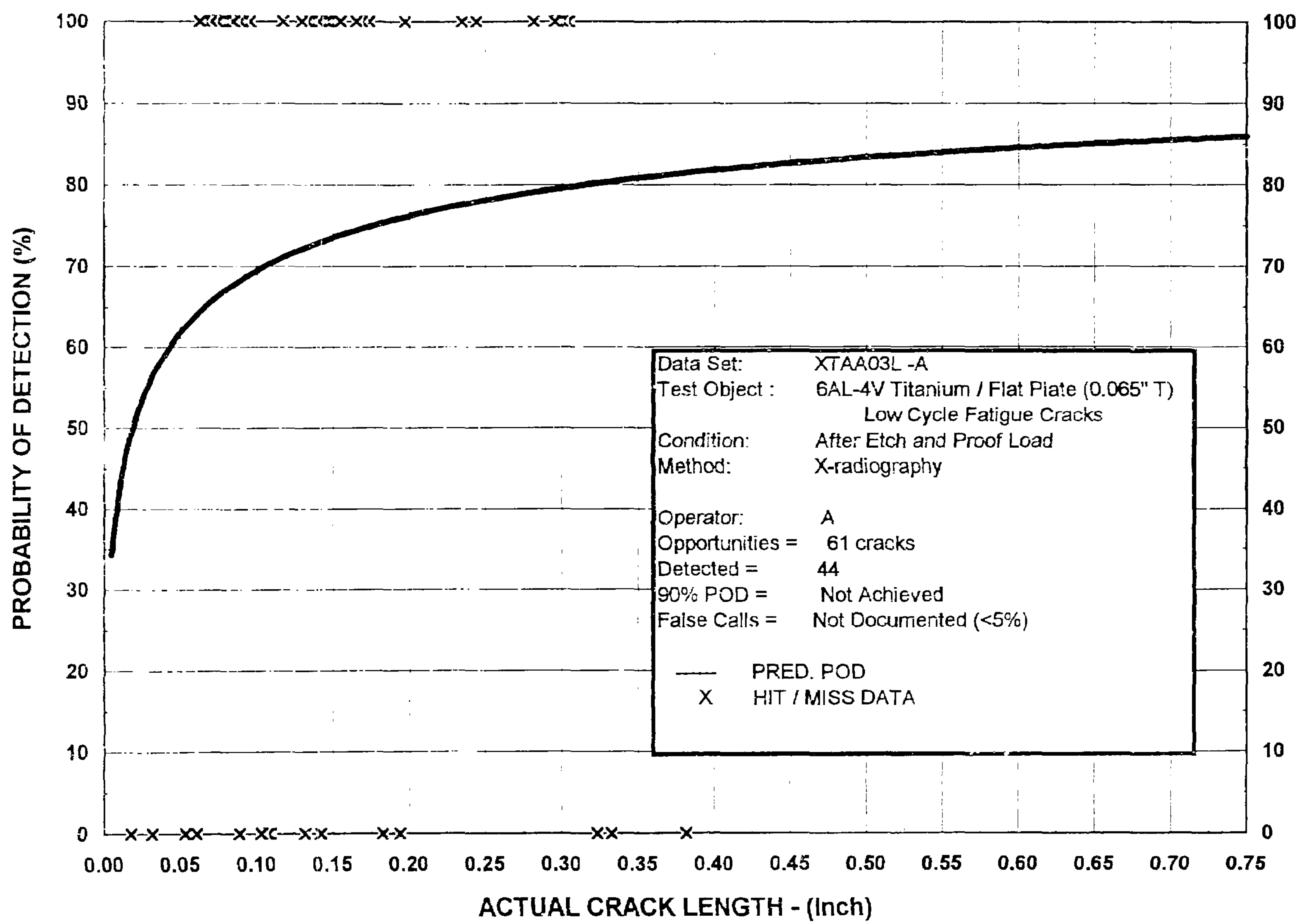
XTAA01L-B
(0.065 " T)



XT - 03 (2)A, TITANIUM FLAT PLATE

06/95

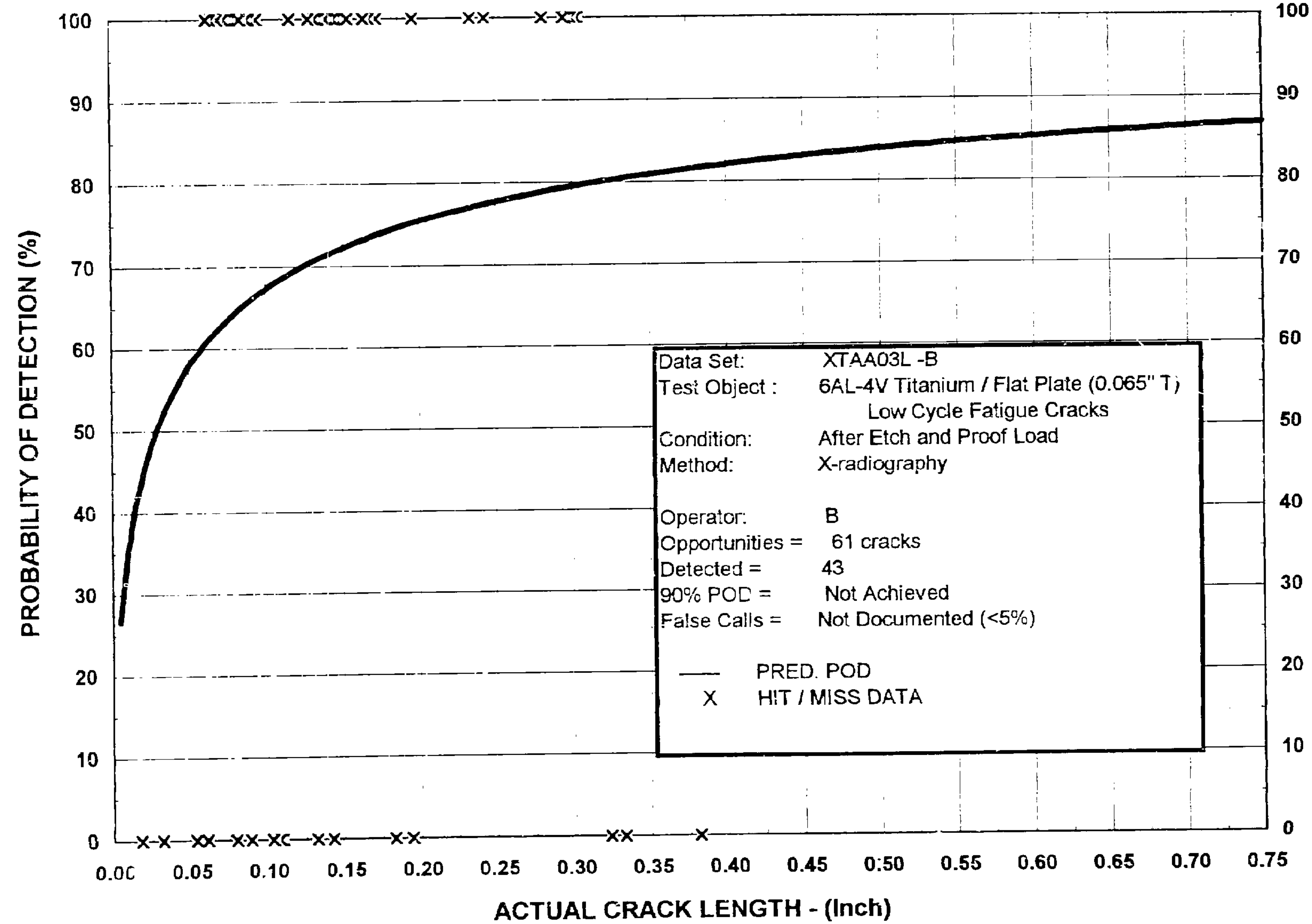
XTAA01L-C
(0.065 " T)



XT - 03 (2)A, TITANIUM FLAT PLATE

06/95

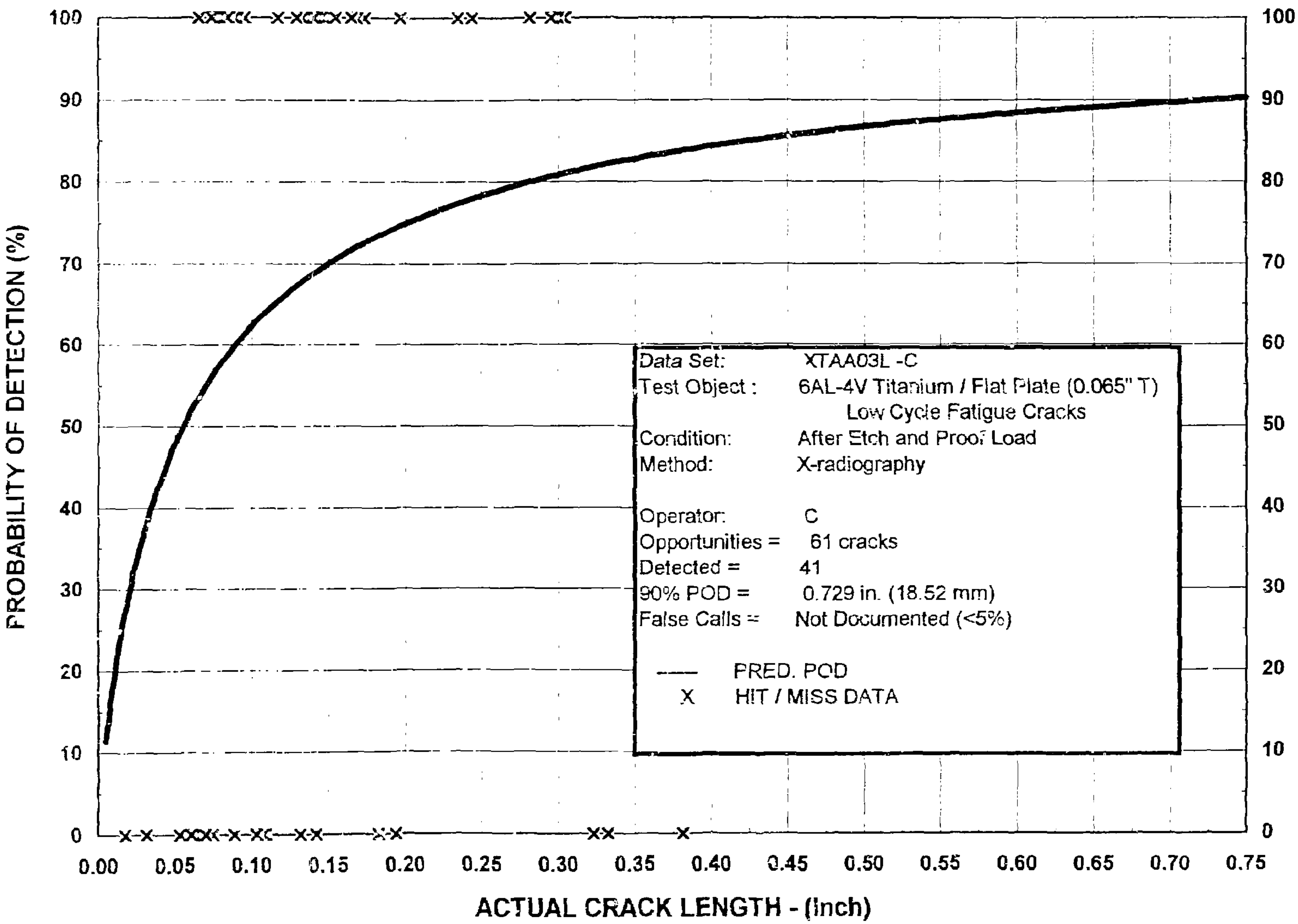
XTAA03L-A
(0.065" T)



XT - 03 (2)A, TITANIUM FLAT PLATE

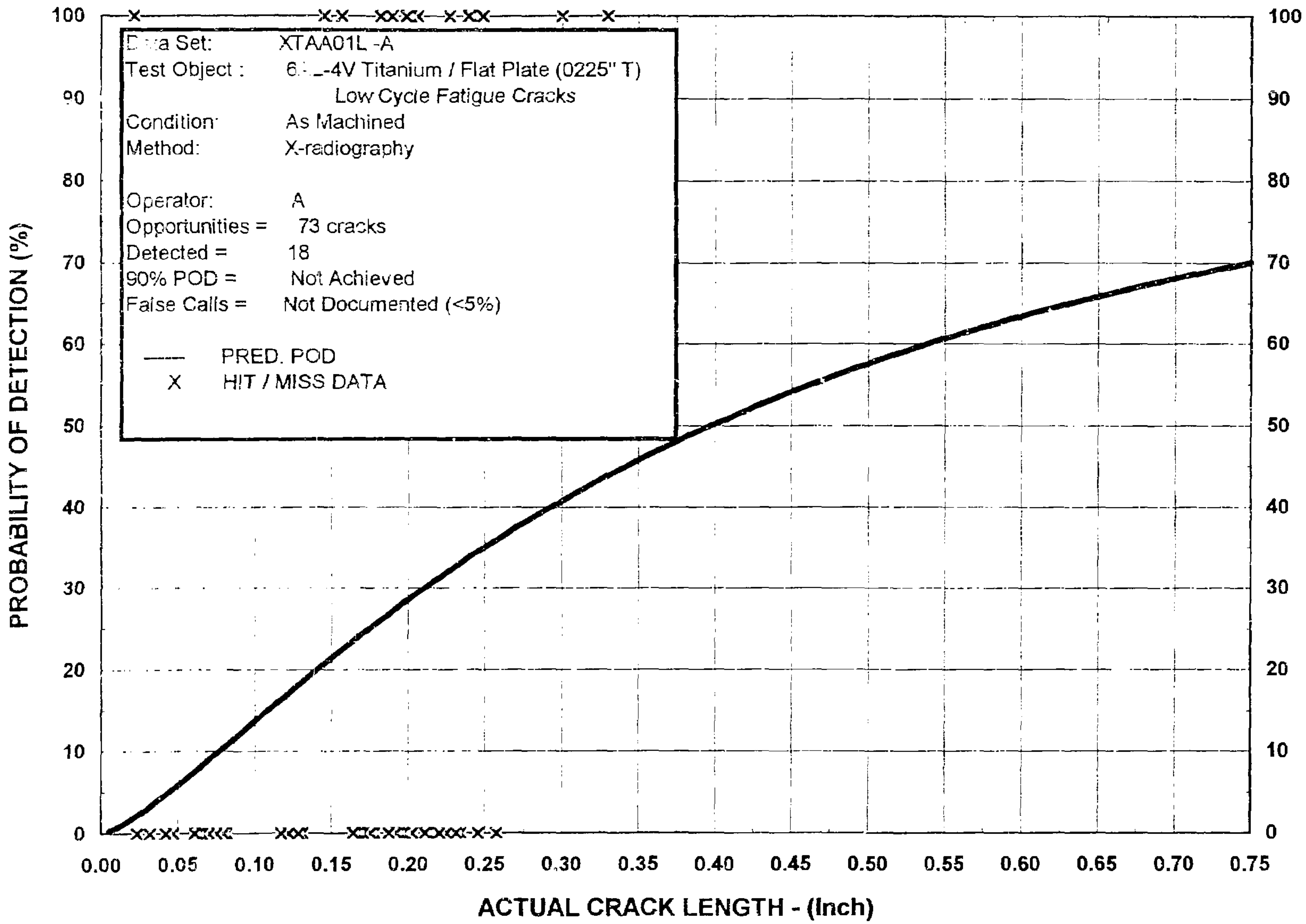
06/95

XTAA03L-B
(0.065" T)



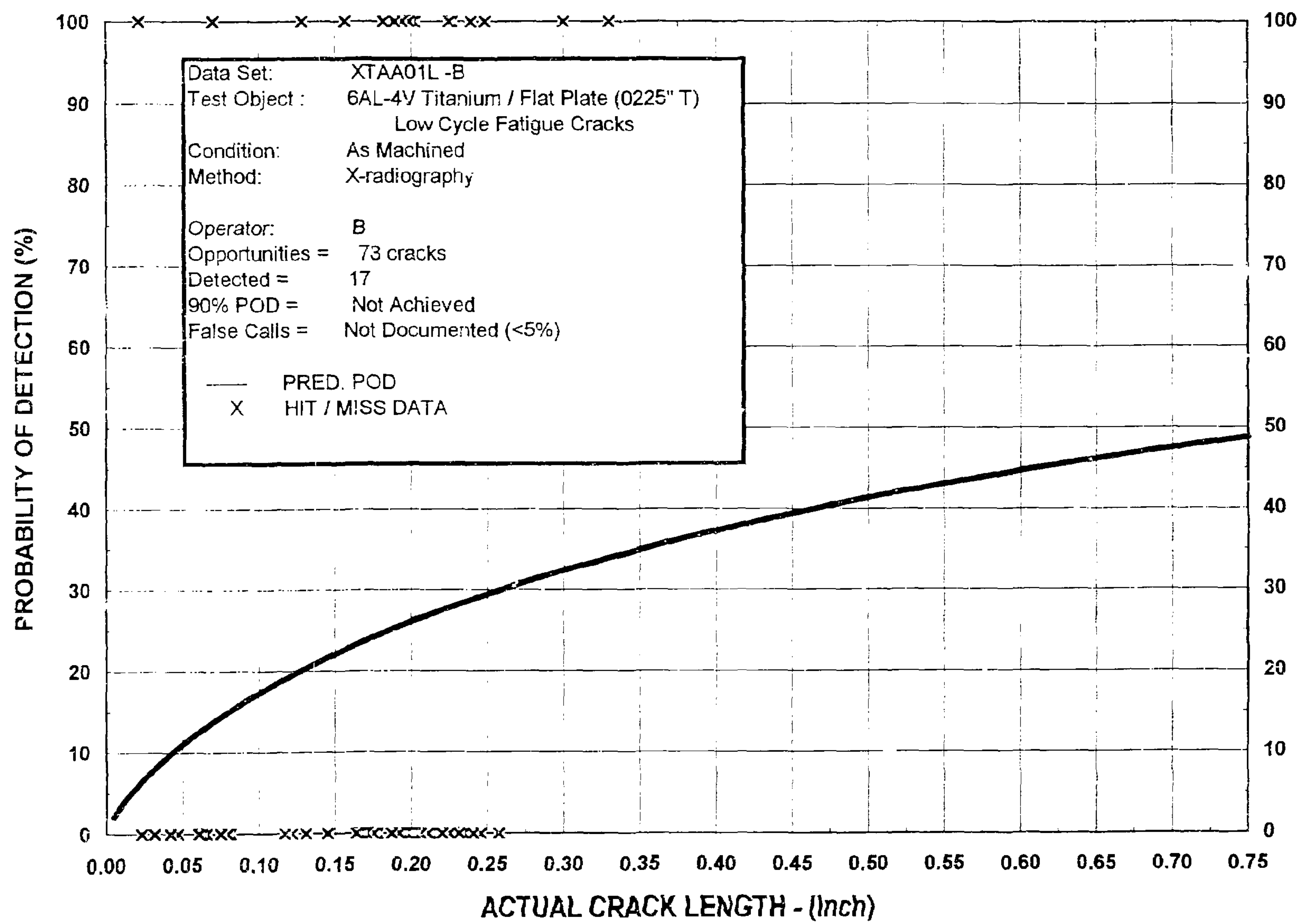
XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

XTAA03L-C
(0.065" T)



XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

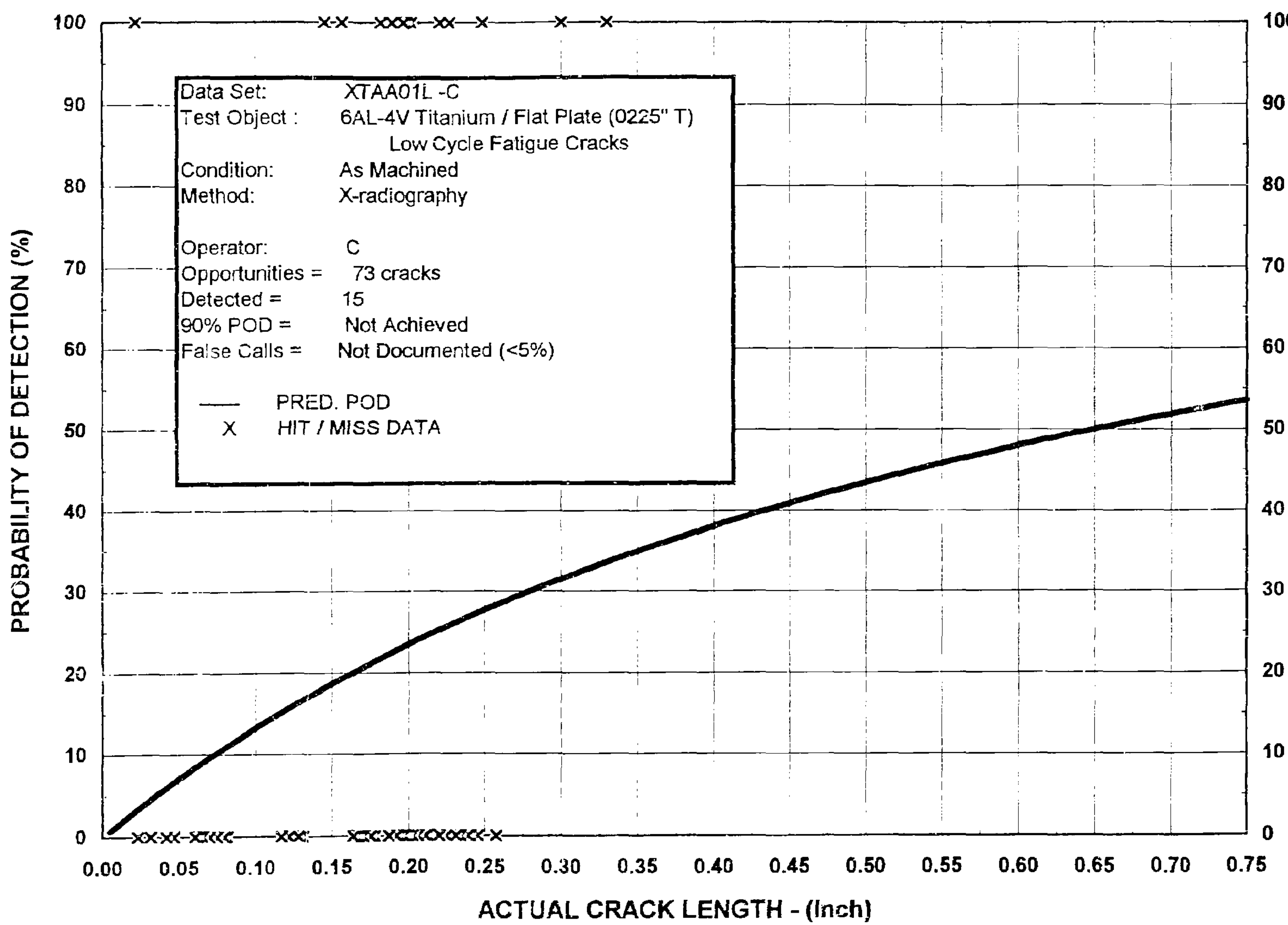
XTAA01L-A
(0.225" T)



XT - 03 (2)A, TITANIUM FLAT PLATE

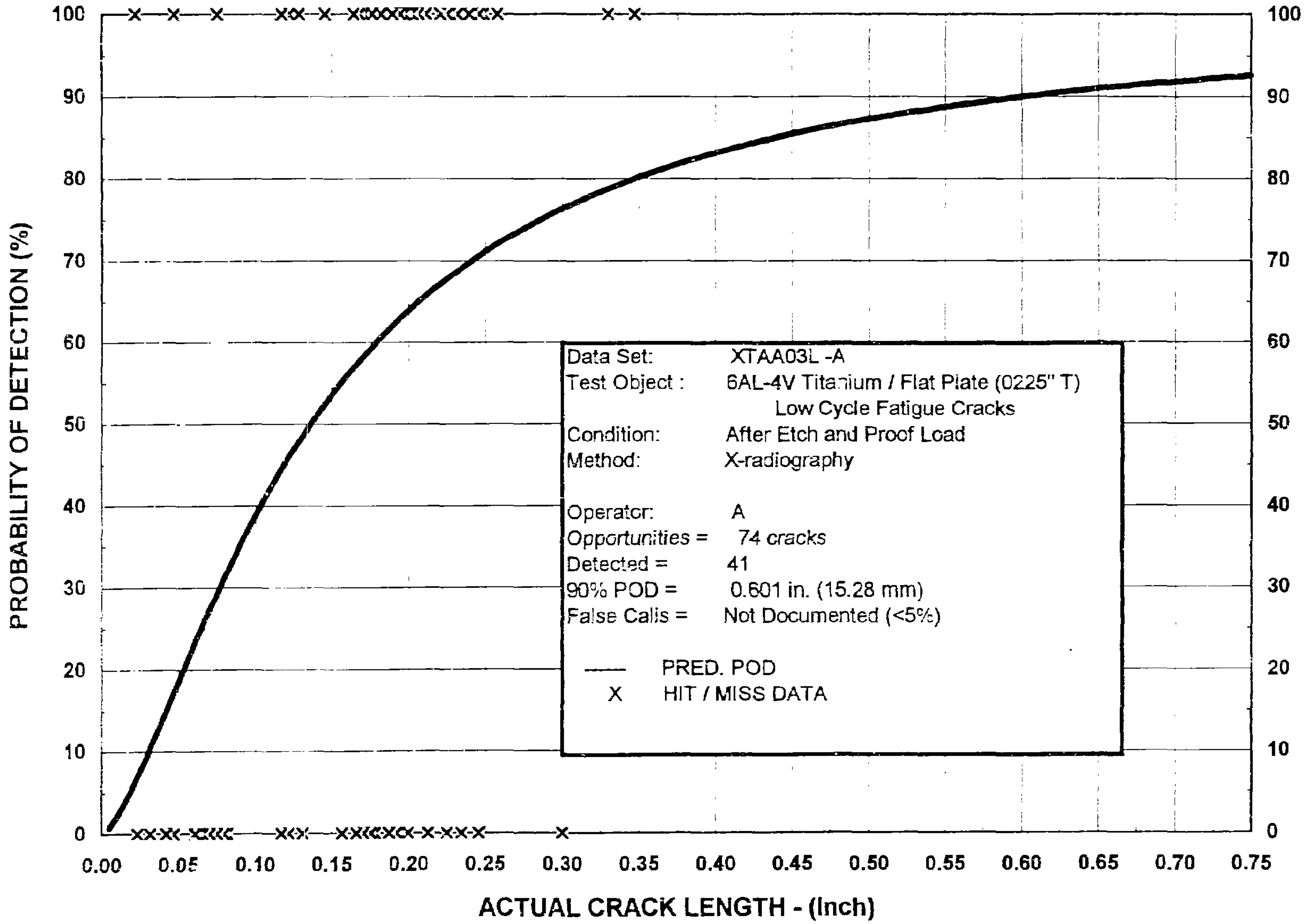
06/95

XTAA01L-B
(0.225" T)



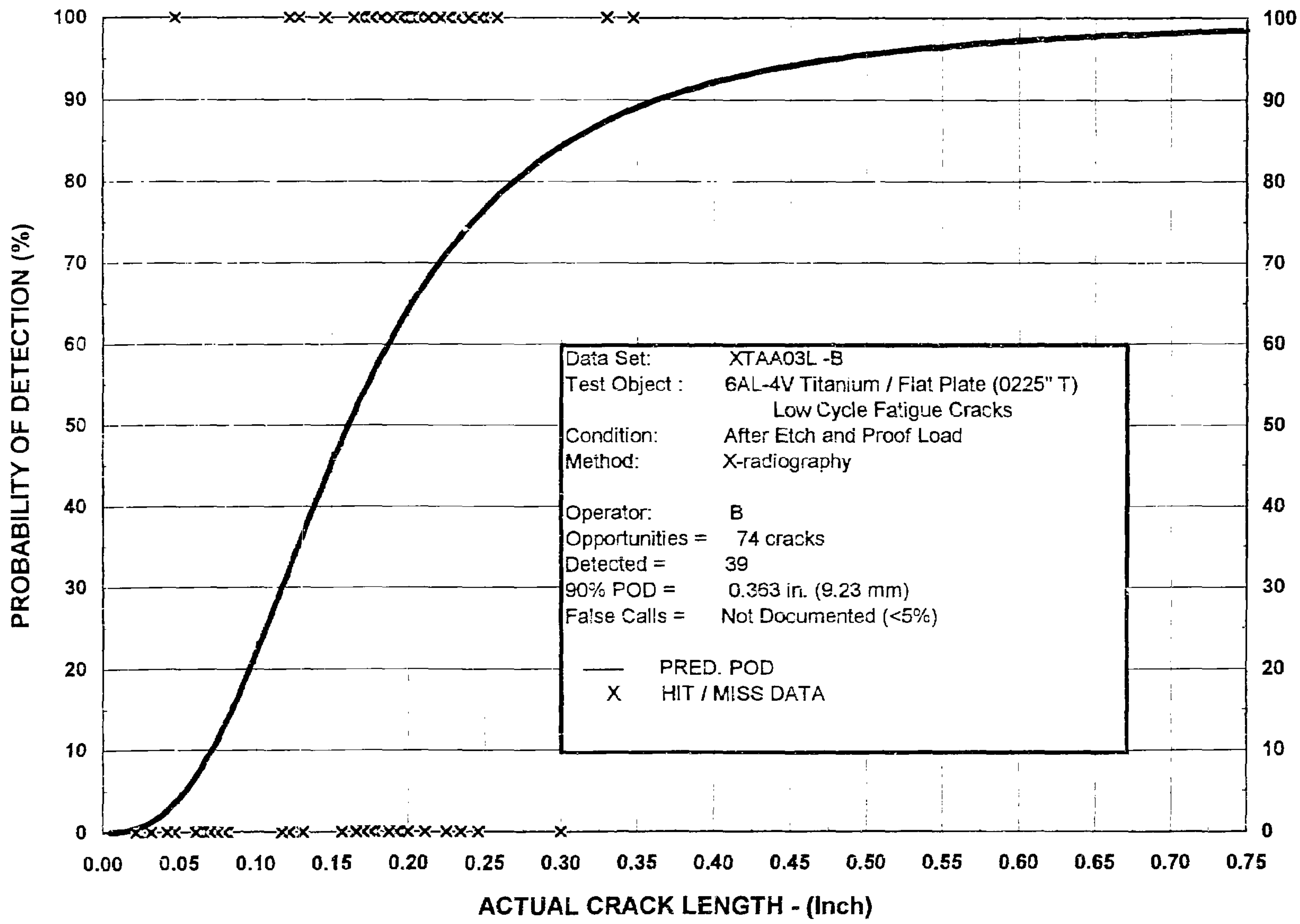
XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

XTAA01L-C
(C.225" T)



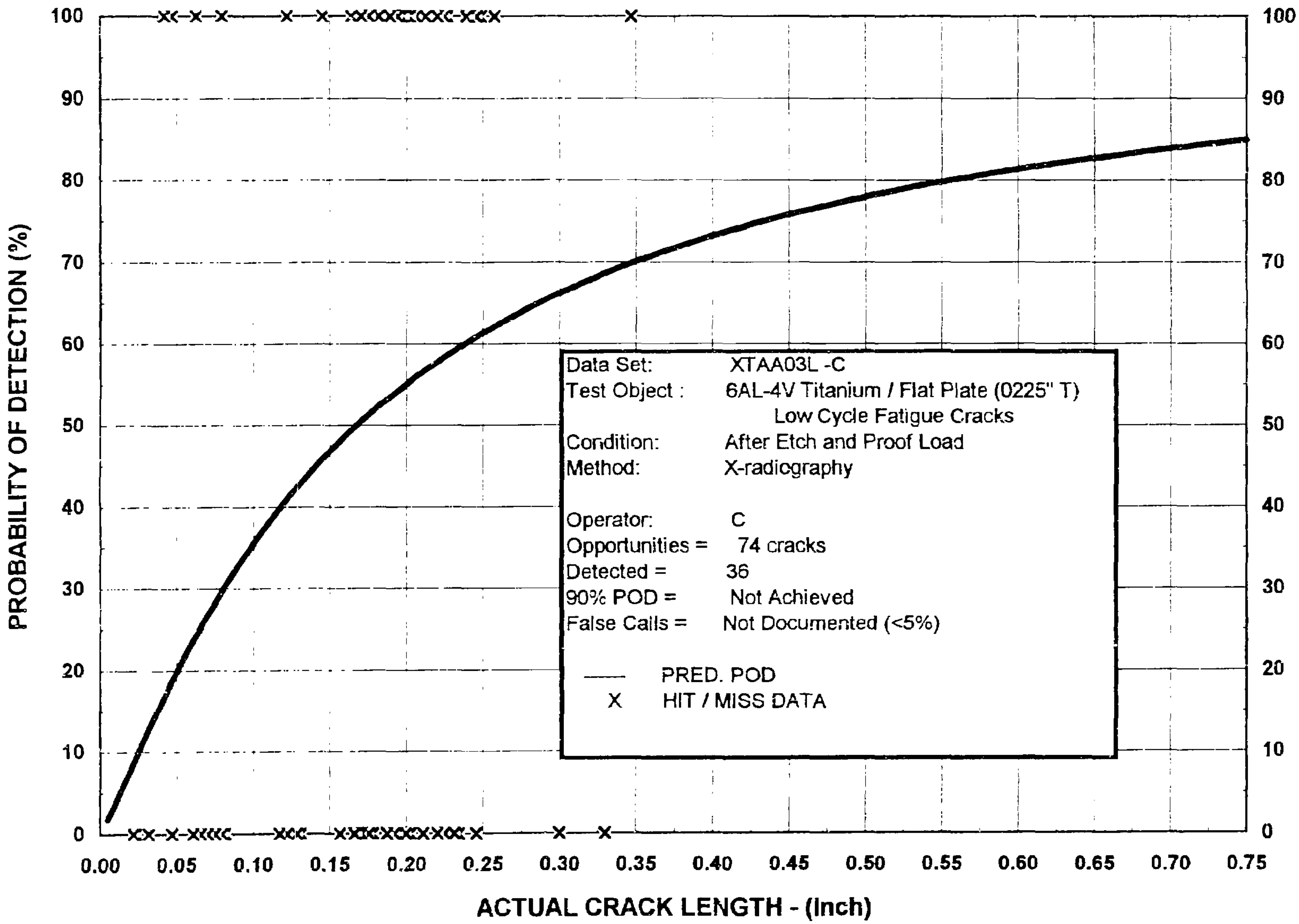
XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

XTAA03L-A
(0.225" T)



XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

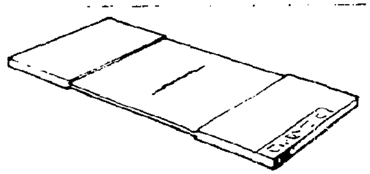
XTAA03L-B
(0.225" T)



XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

XTAA03L-C
(0.225" T)

XT 03 (2)B CRACK DEPTH	DATA SET DESCRIPTION
METHOD:	X-radiography
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiography, Kodak Type M film/ automatic film process / manual read
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Titanium plate - 6Al4V
TEST OBJECT THICKNESS:	0.085 and 0.225 inch nominal
TEST OBJECT CONDITION:	-01,"As Machined"; -03,"After Proof"
SURFACE FINISH:	125 RMS - *representative of good machining* practices
APPLICATION:	Manual Reading / Manual Recording
DATA SET IDENTIFIER:	XTAA01D - A,B,C Separated into 0.065 in. and 0.225 in. thicknesses
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	60 (0.065 in.) and 74 (0.225 in.) Cracks. All cracks not inspected by all operators.
DETECTED:	(0.065 in.)01D, A=29,B=25, C=29: 03D.A=44.B=43.C=41;(0.225 in.)01D,A=18,B=17,C=15;03D,A=41,B=39,C=34
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-151098. Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen. **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner. NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace. Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria.
	Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	90% POD by crack depth

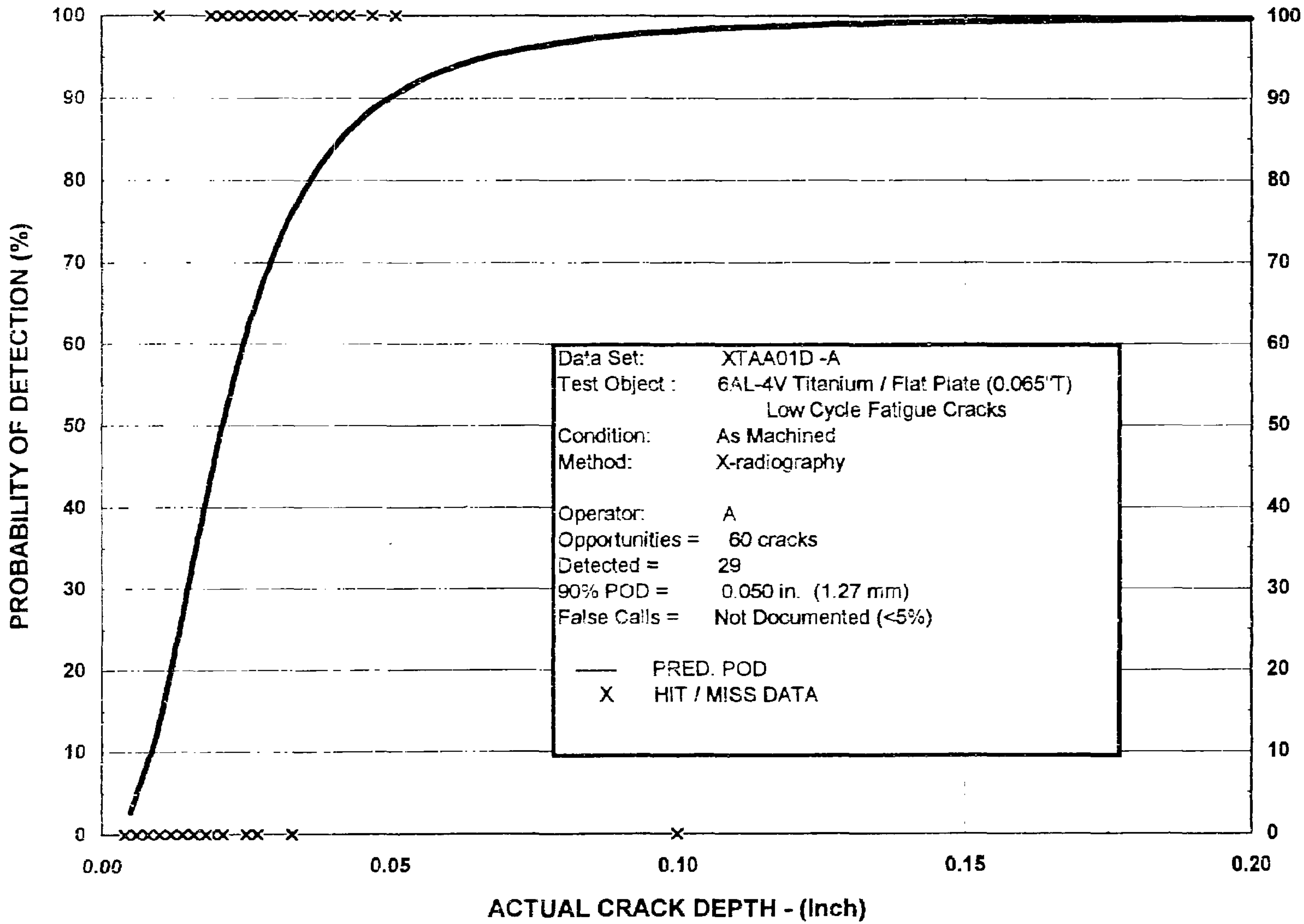


(0.065 in.) -01 ;	- 03;	(0.225 in.) -01	-03
A= 0.0.50 in.	A= N.A.	A=N.A..	A= N.A.
B= 0.048 in.	B= N.A.	B= 0.111 in.	B= N.A..
C= 0.036 in..	C= N.A.	C= N.A.	C= 0.176 in.

XT - 03 (2)B, CRACK DEPTH FOR TWO DIFFERENT THICKNESSES

6/95

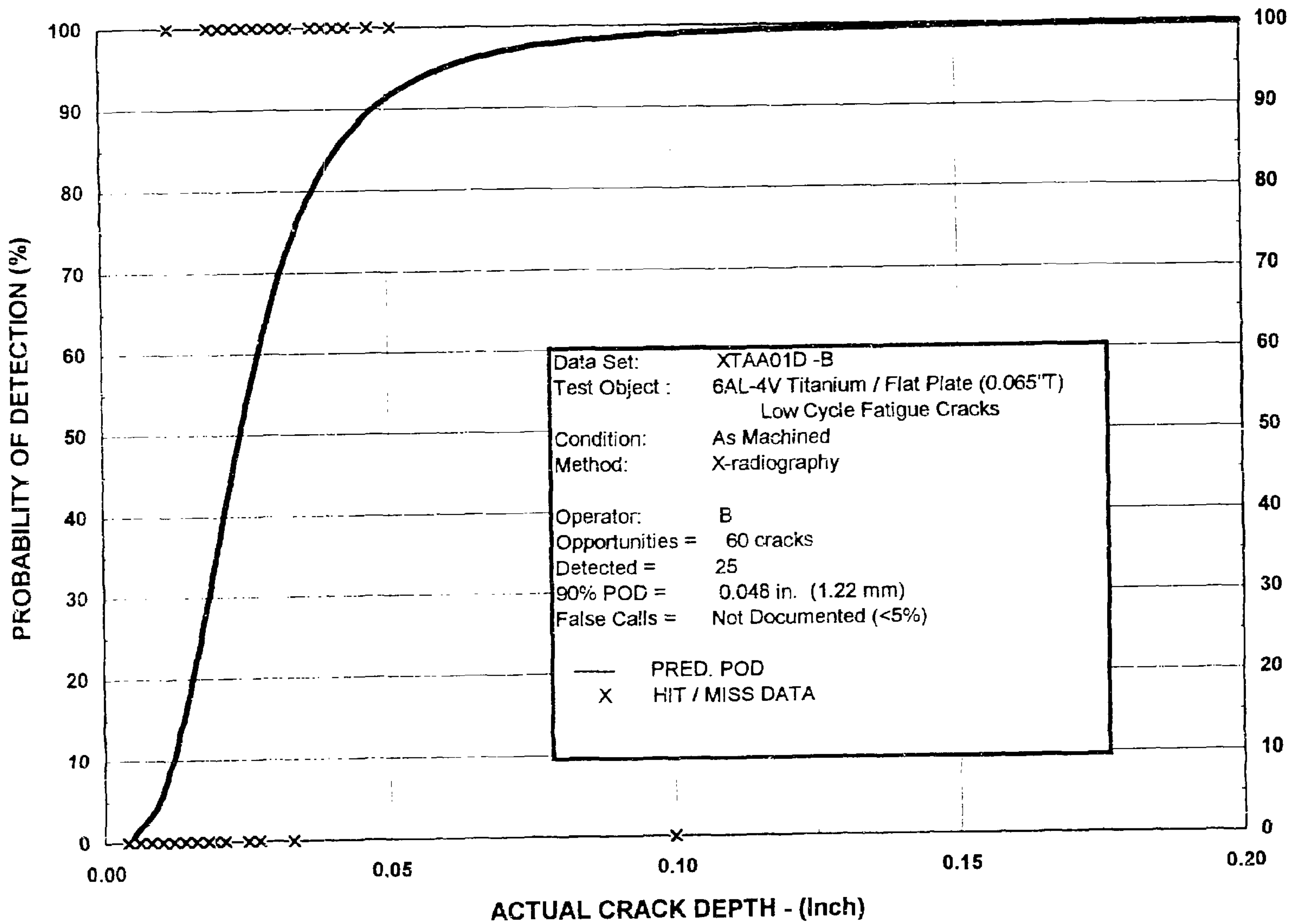
X-RADIOGRAPHY
TITANIUM PANELS



XT - 03 (2)B, TITANIUM FLAT PLATE

06/95

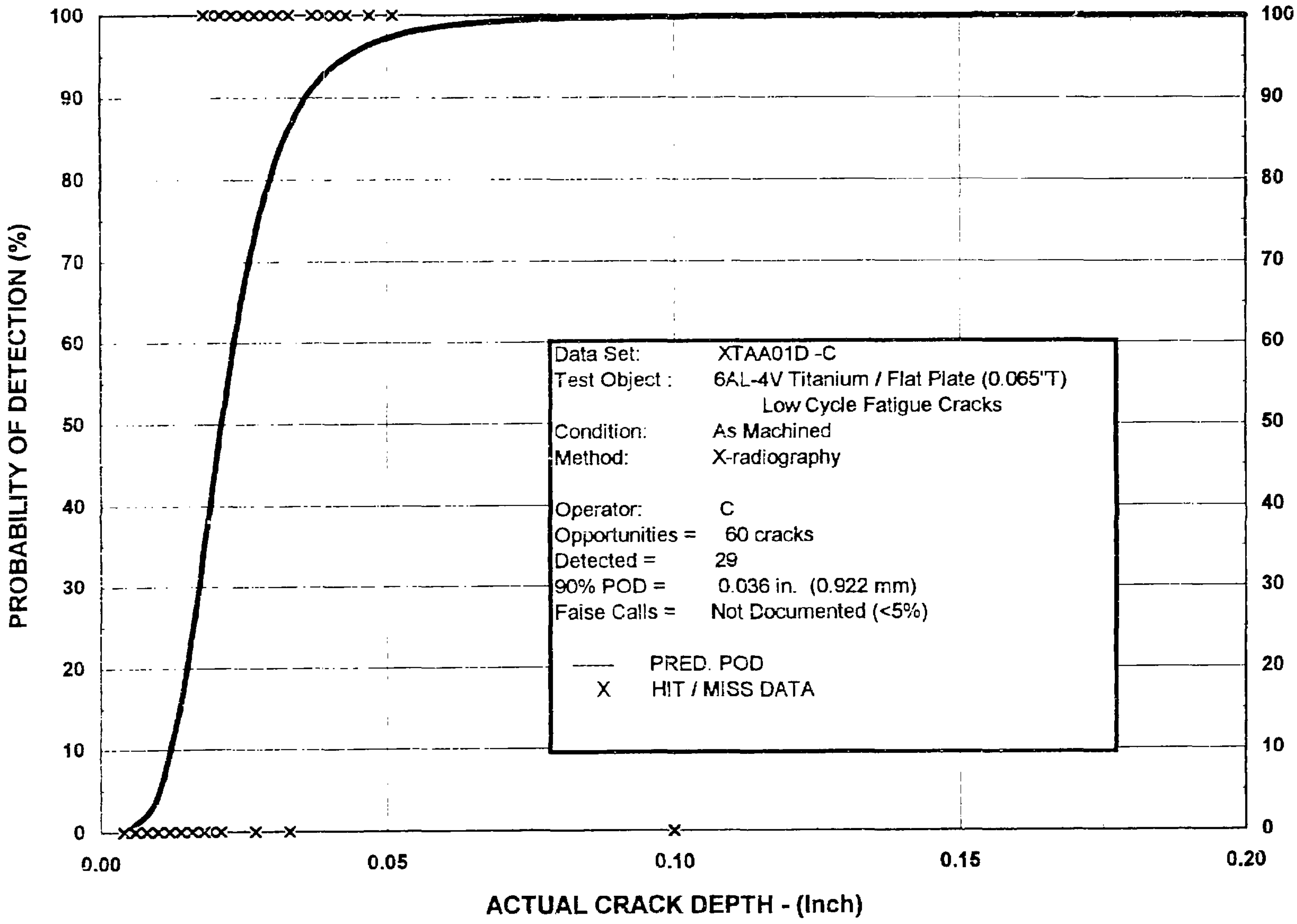
XTAA01D-A
(0.065 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE

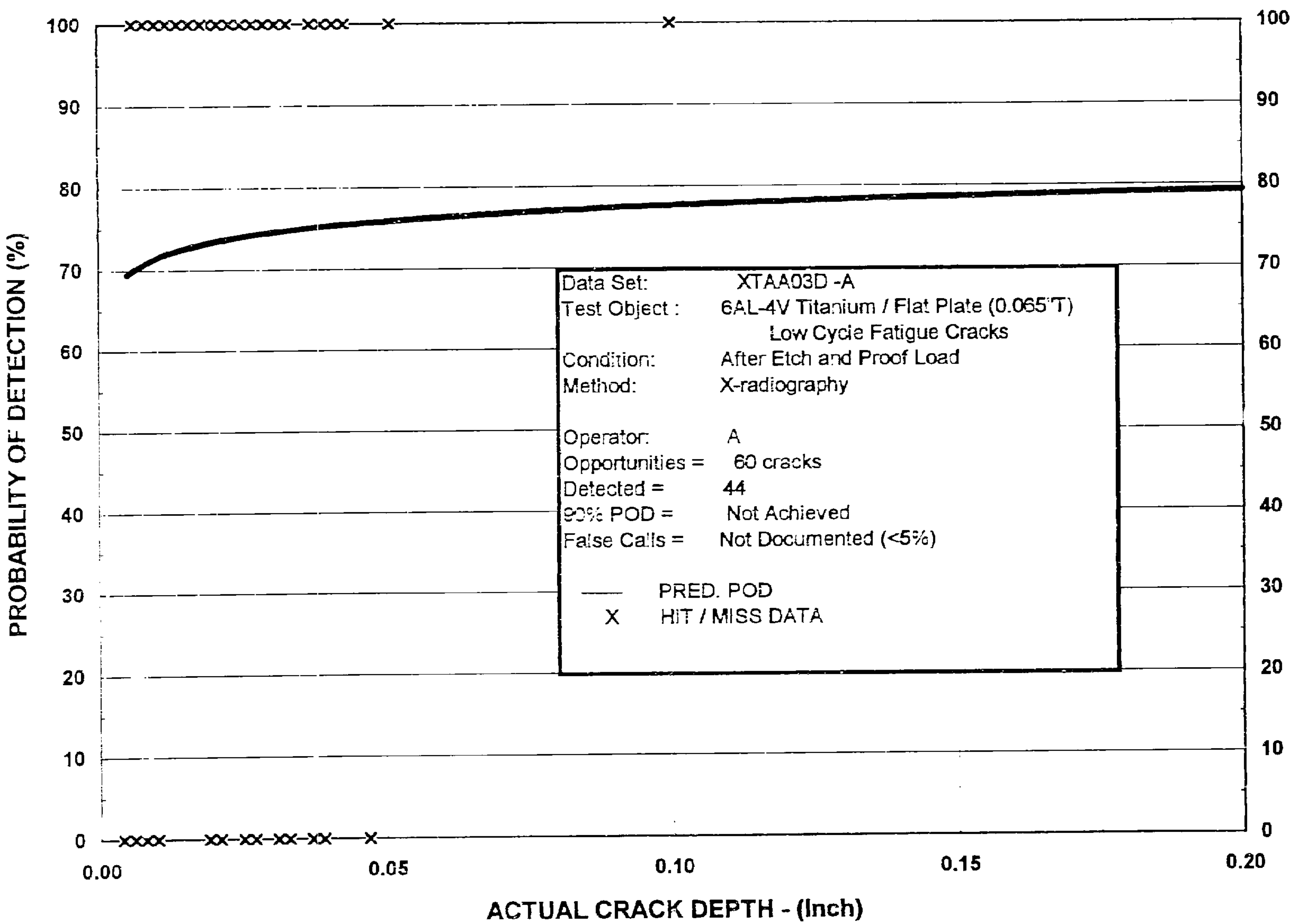
06/95

XTAA01D-B
(0.065 " T)



XT - 03 (2)A, TITANIUM FLAT PLATE
06/95

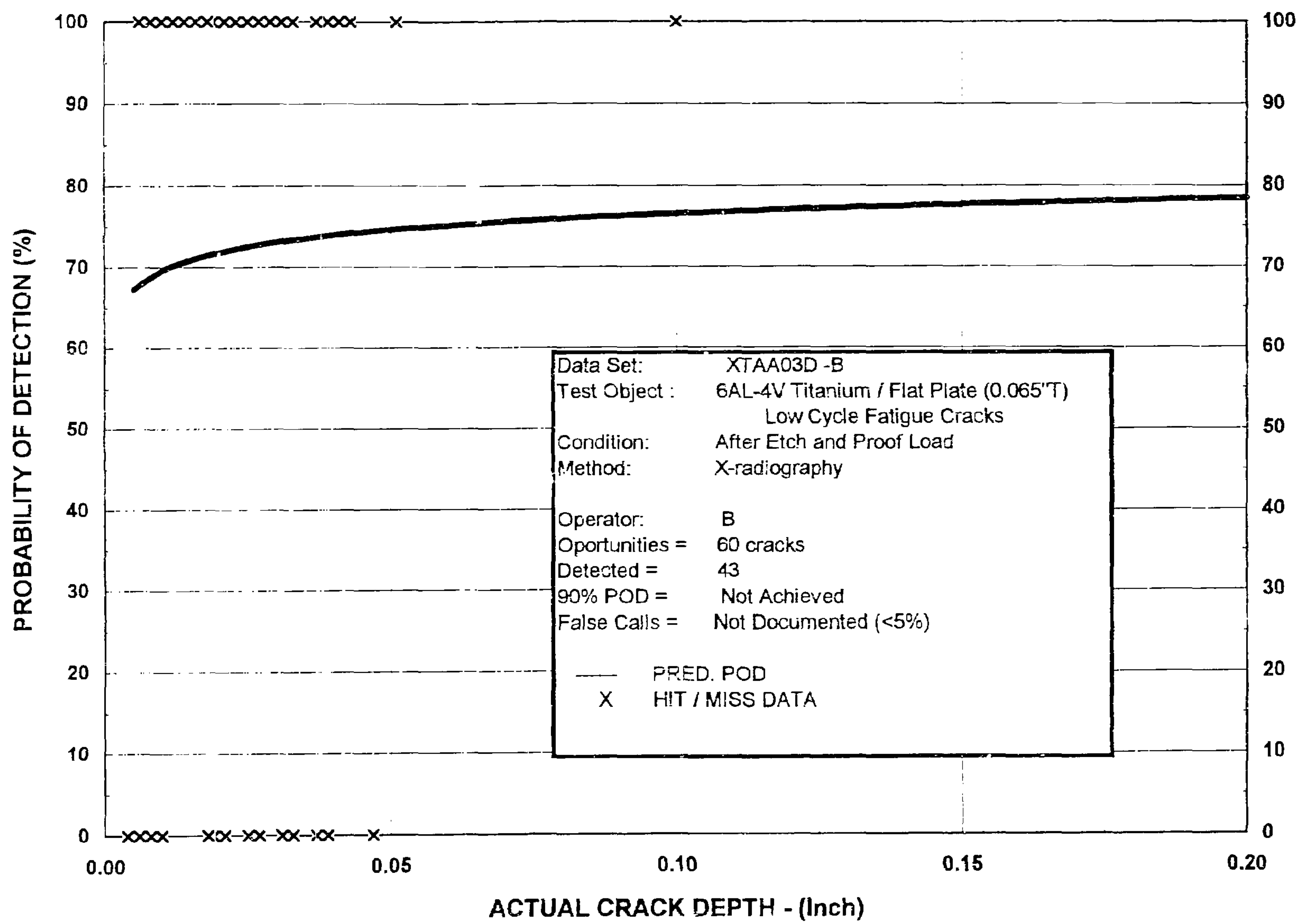
XTAA01D-C
(0.065 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE

06/95

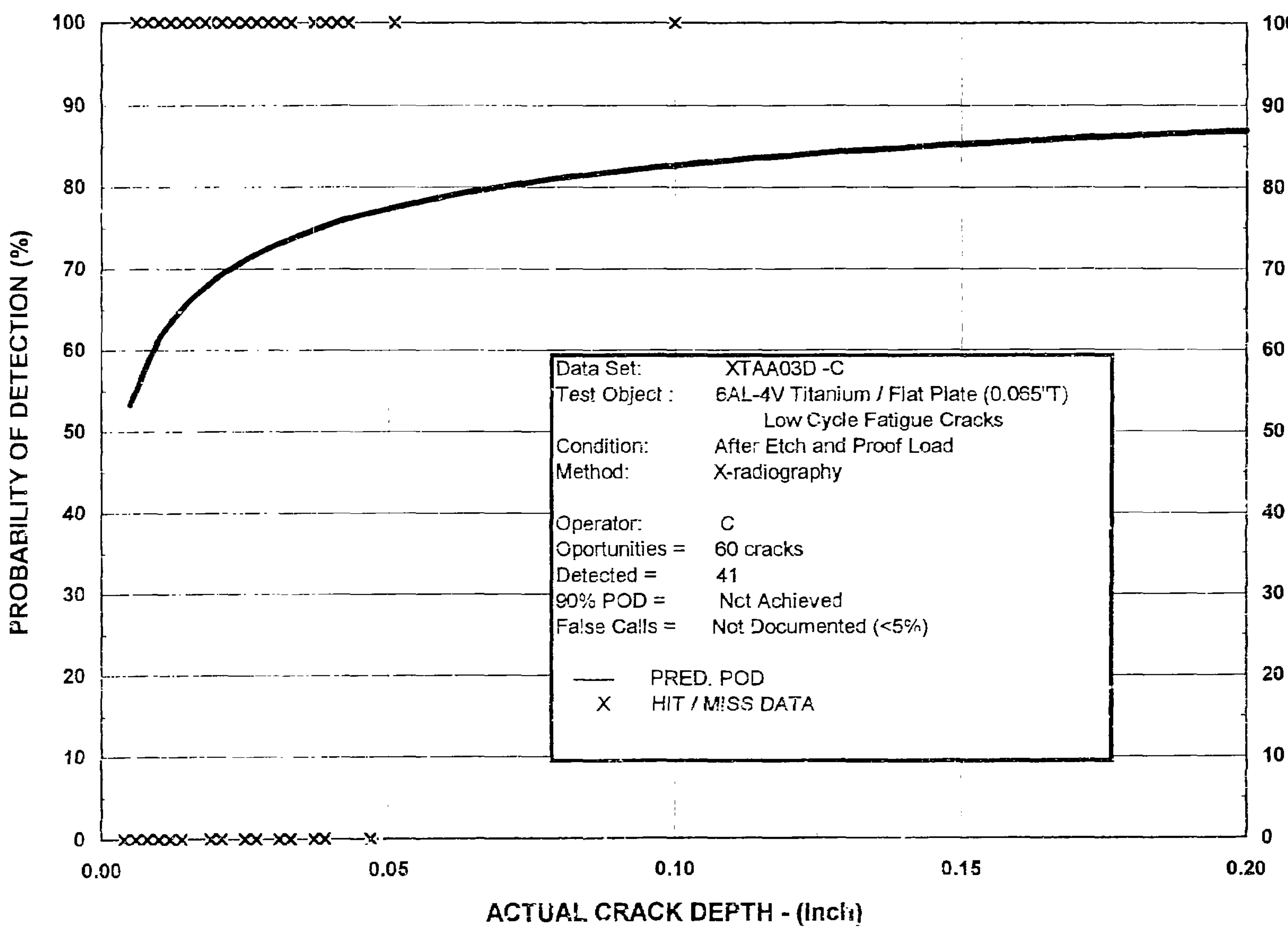
XTAA03D-A
(0.065 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE

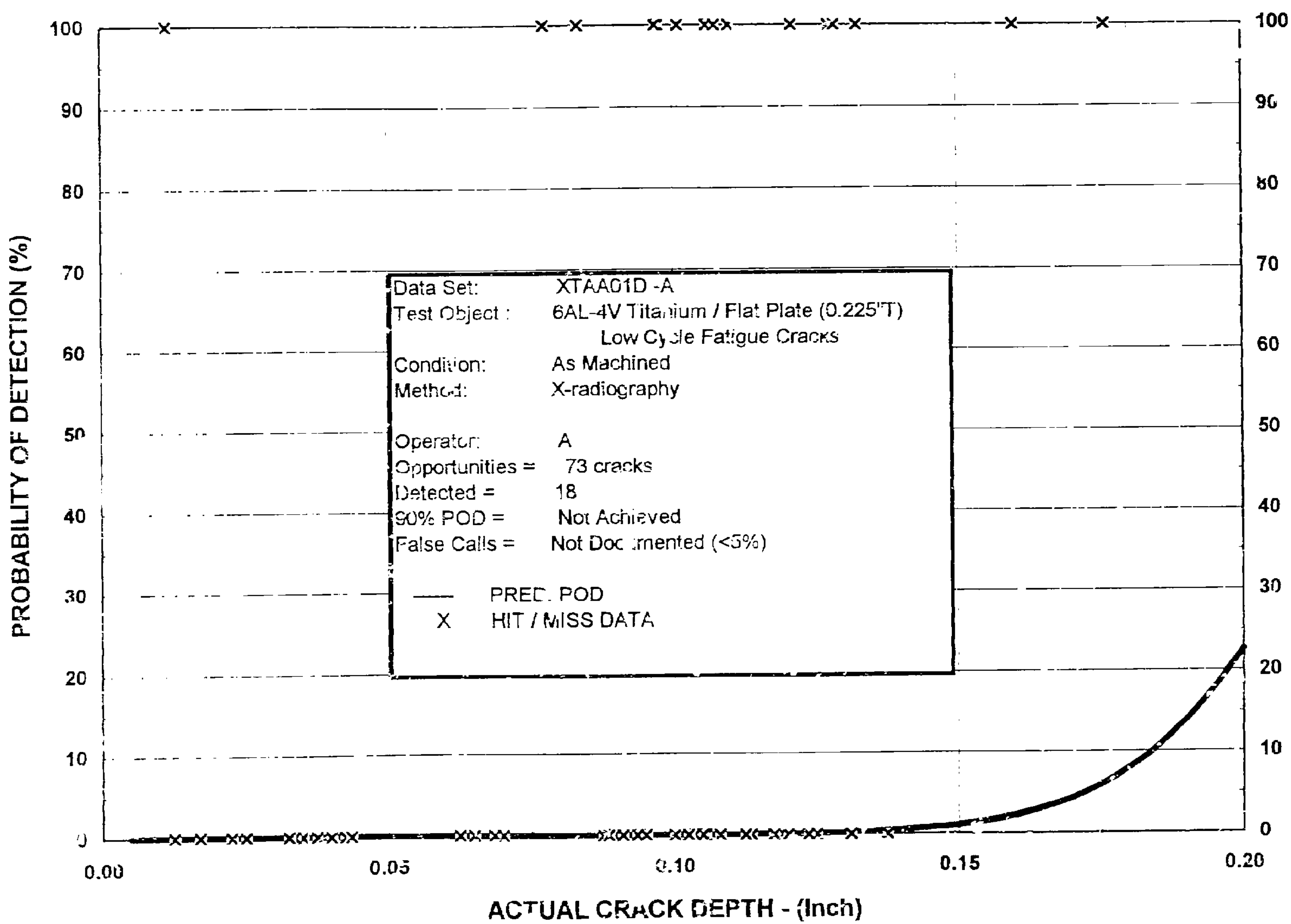
06/95

XTAA03D-B
(0.065 " T)



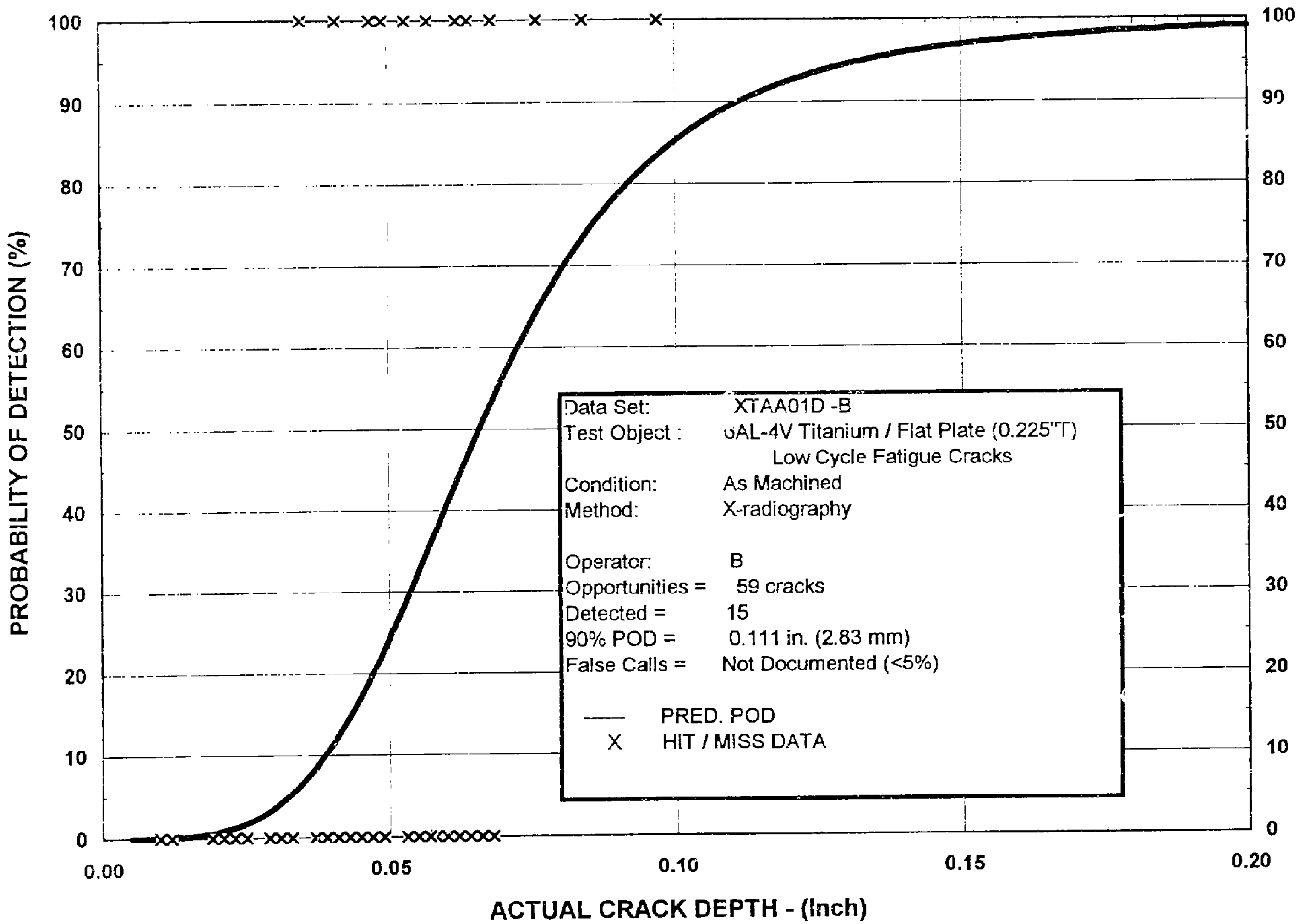
XT - 03 (2)B, TITANIUM FLAT PLATE
06/95

XTAA03D-C
(0.065 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE
06/95

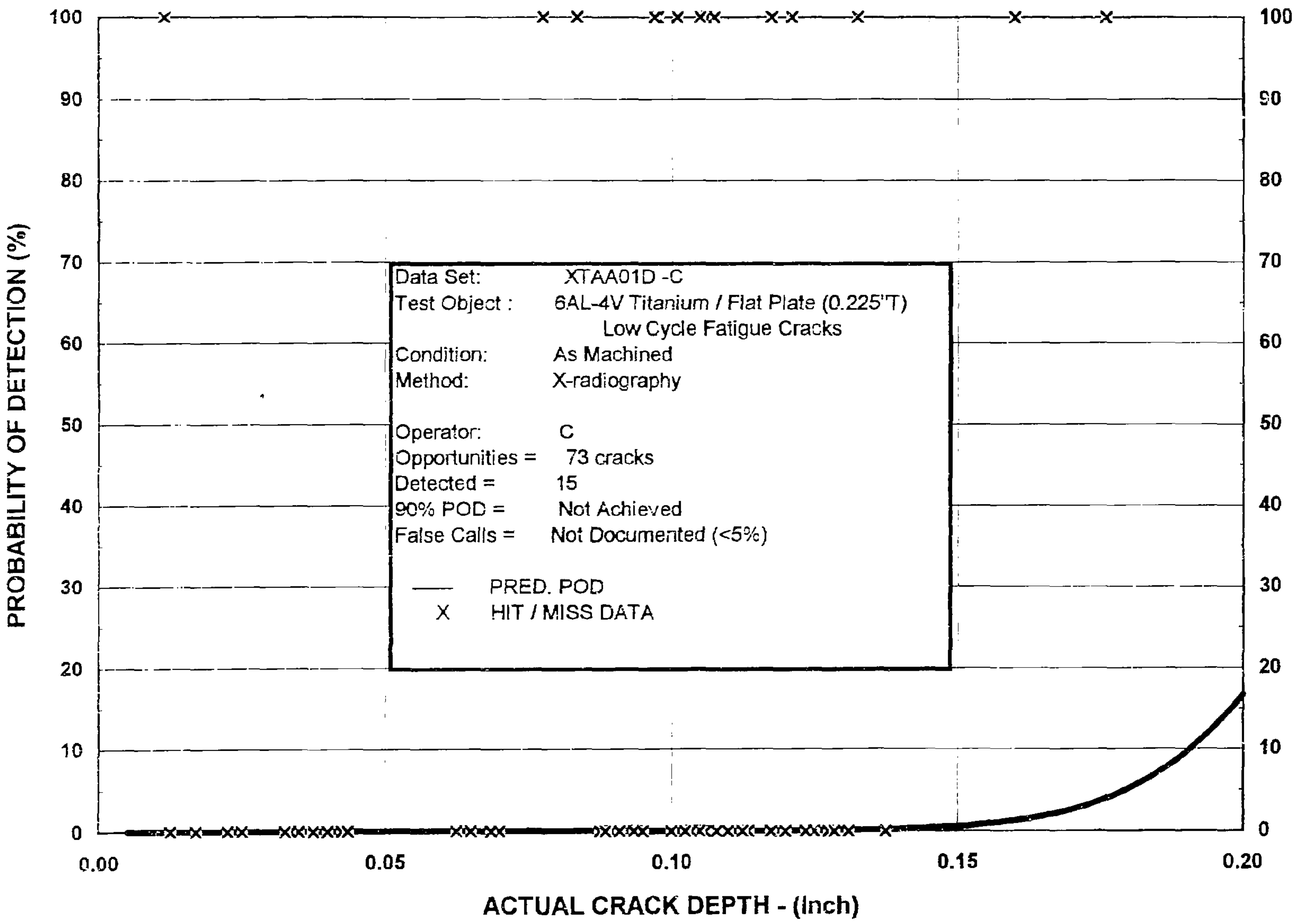
XTAA01D-A
(0.225 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE

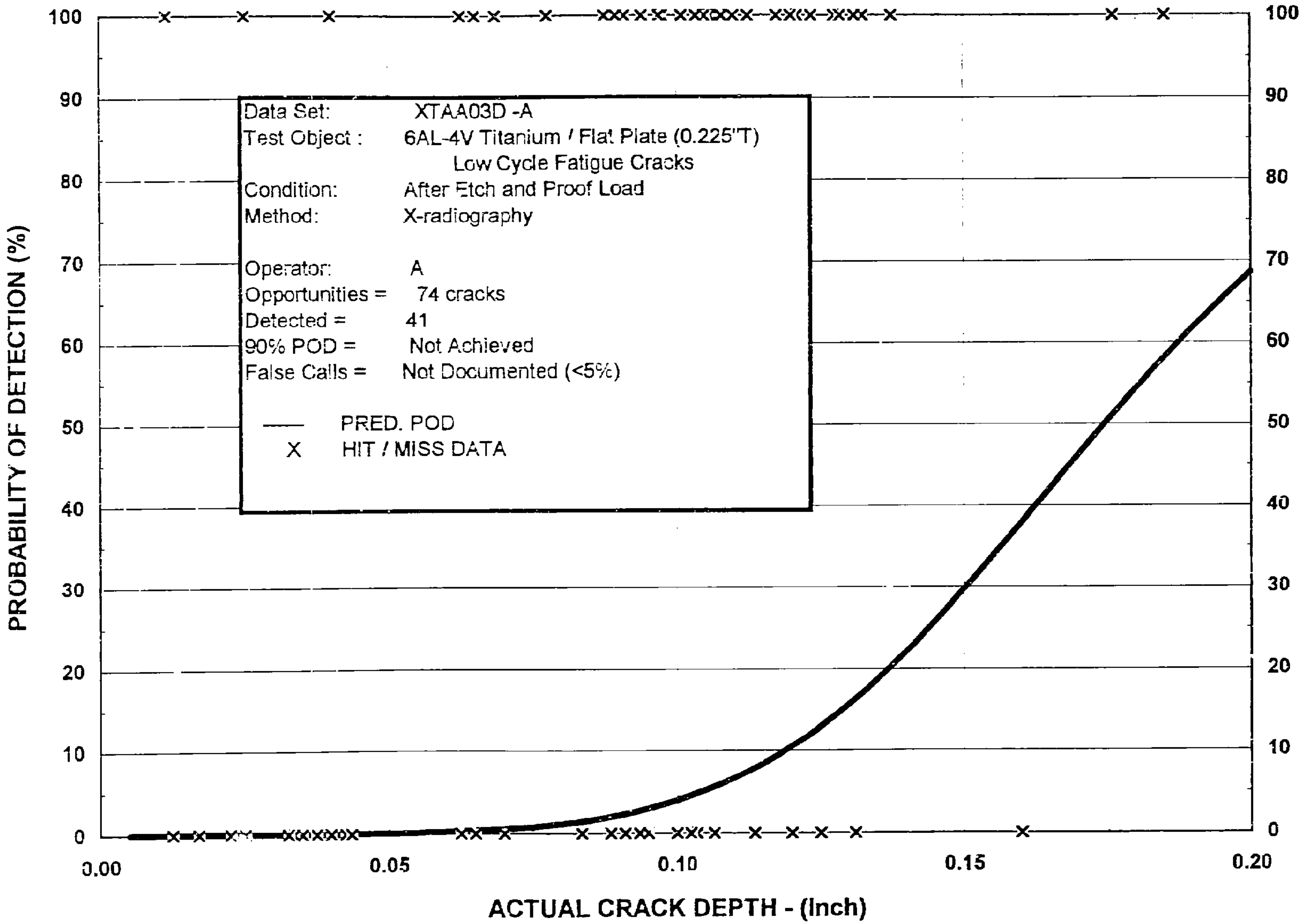
06/95

XTAA01D-B
(0.225 " T)



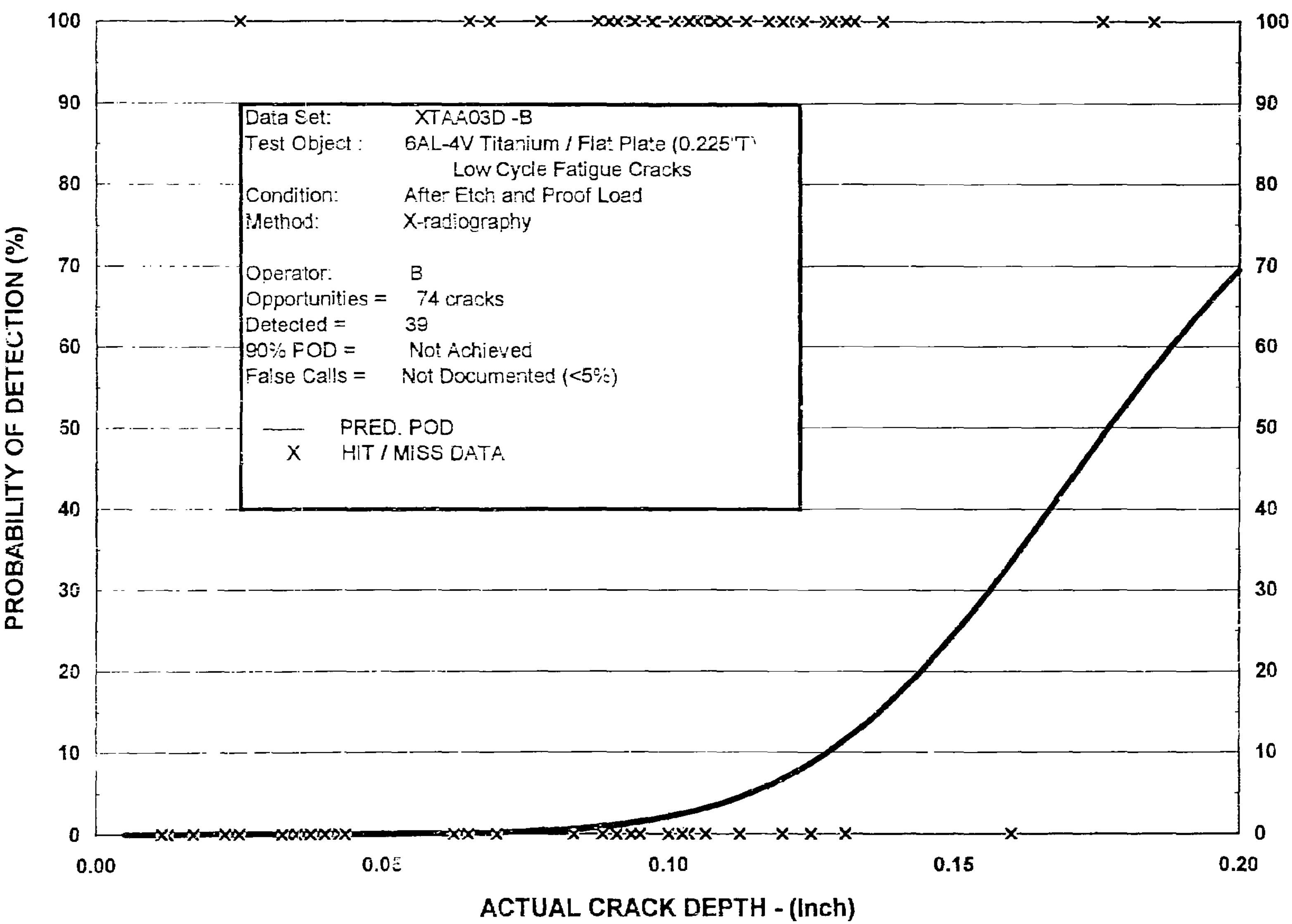
XT - 03 (2)B, TITANIUM FLAT PLATE
06/95

XTAA01D-C
(0.225 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE
06/95

XTAA03D-A
(0.225 " T)

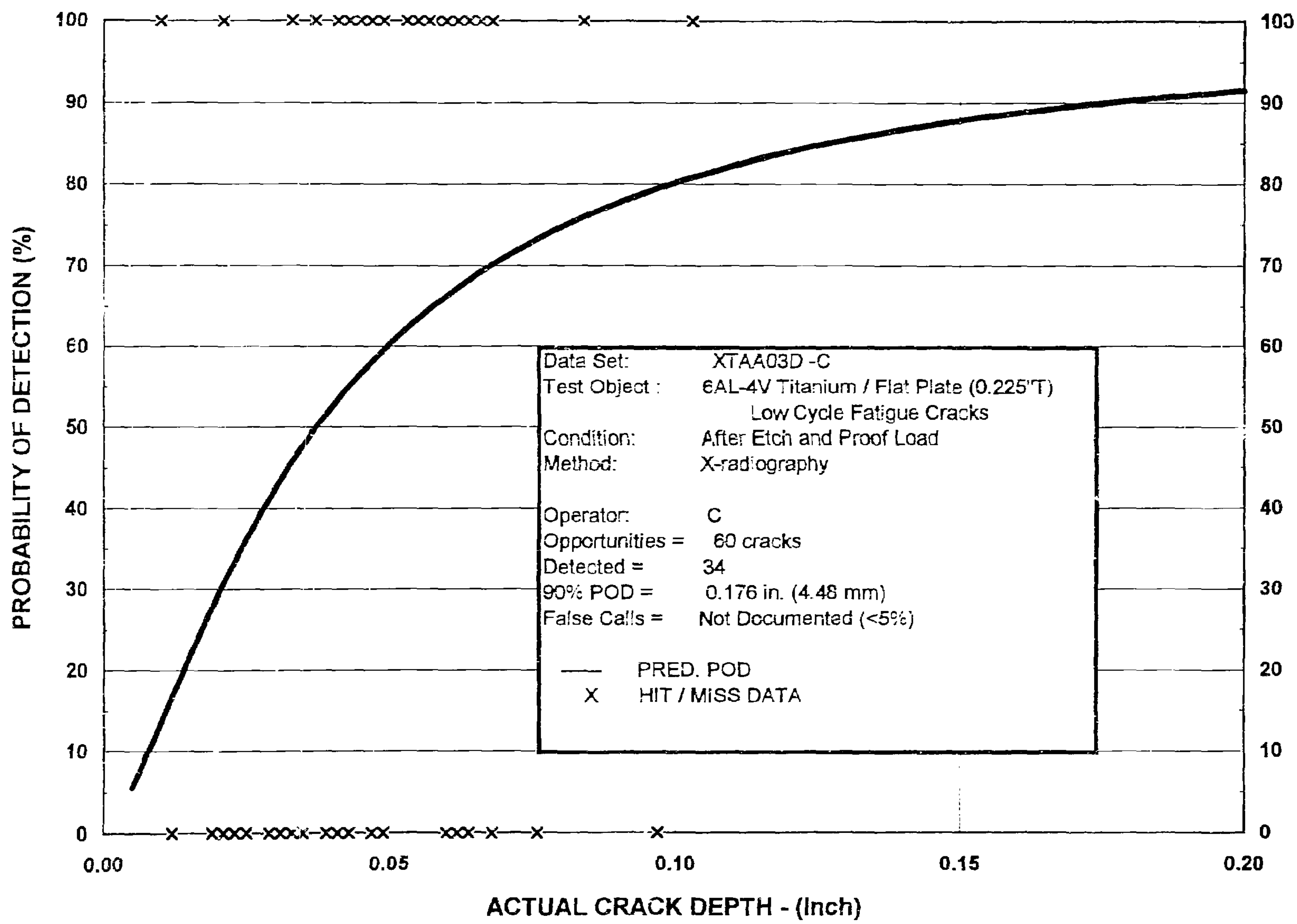


XT - 03 (2)B, TITANIUM FLAT PLATE

06/95

XTAA03D-B

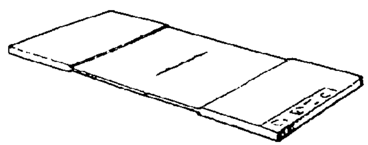
(0.225 " T)



XT - 03 (2)B, TITANIUM FLAT PLATE
06/95

XTAA03D-C
(0.225 " T)

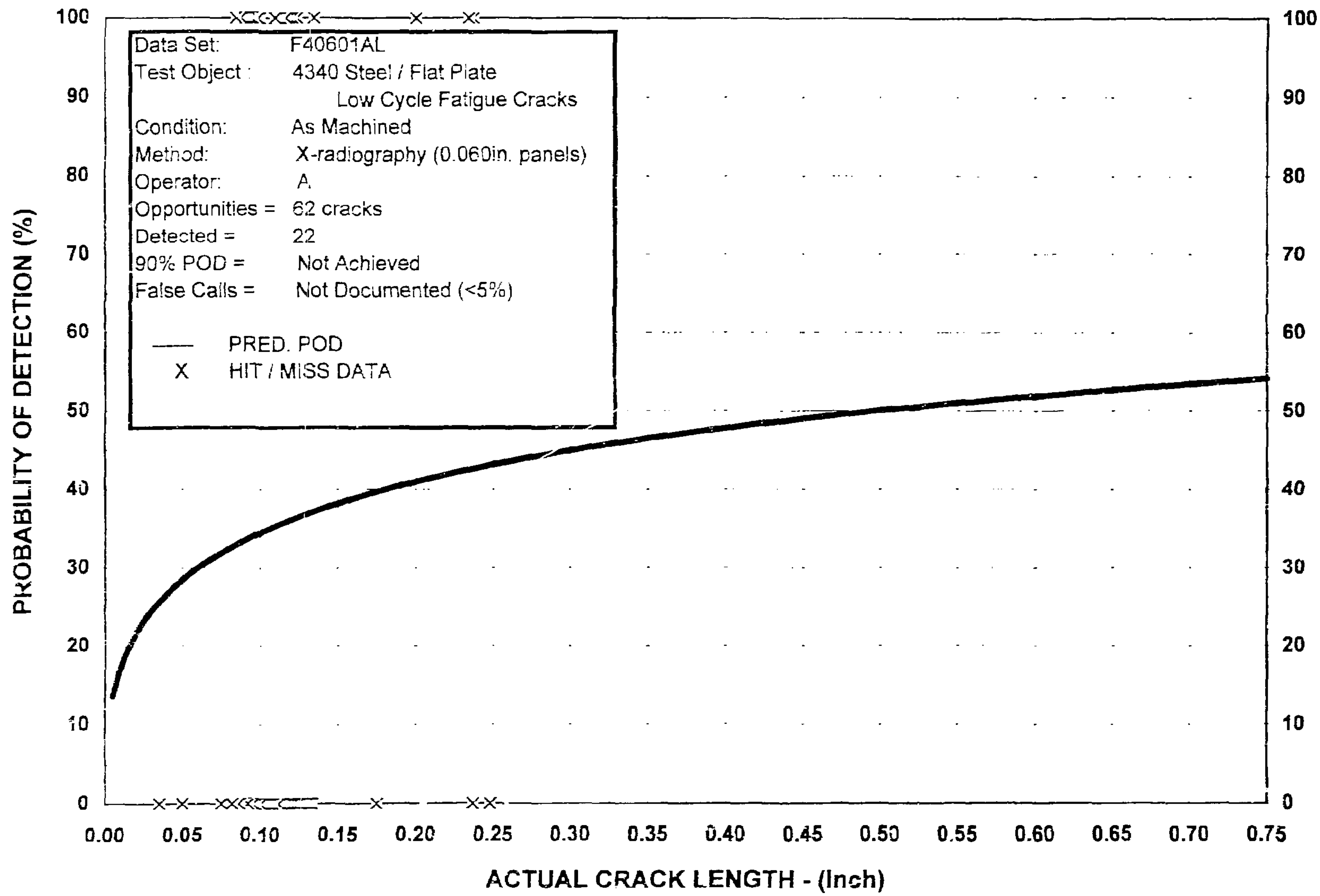
F4060(2)L	**DATA SET DESCRIPTION**
METHOD:	X-Radiographic Inspection by CRACK LENGTH - 0.060" panel thickness
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiographic inspection; Kodak Type M Film; Automatic Processing; Exposure optimized to test specimens
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.060 inch nominal
TEST OBJECT CONDITION:	F40601,"As Machined"; F40603,"After Etch and Proof Loading"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Processing / Manual Inspection (Wet Horizontal / Uresco 228 fluorescent particles)
DATA SET IDENTIFIER:	F40601-A,B,C; F40603-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	80 Cracks -Variation in the number inspected during each sequence
DETECTED:	F40601 - A = 22/62. B= 22/62, C= 23/62; F40603 - A= 40/64, B= 34/64, C= 39/64
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, **Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium**, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



CRACK LENGTH		
90% POD	"AS MACHINED"	"AFTER PROOF"
	A= Not Achieved	A= 0.263in. (6.67mm)
	B= Not Achieved	B= 0.486in. (12.35mm)
	C= Not Achieved)	C= 0.263in. (6.67mm)

F4060(2)L
8/96

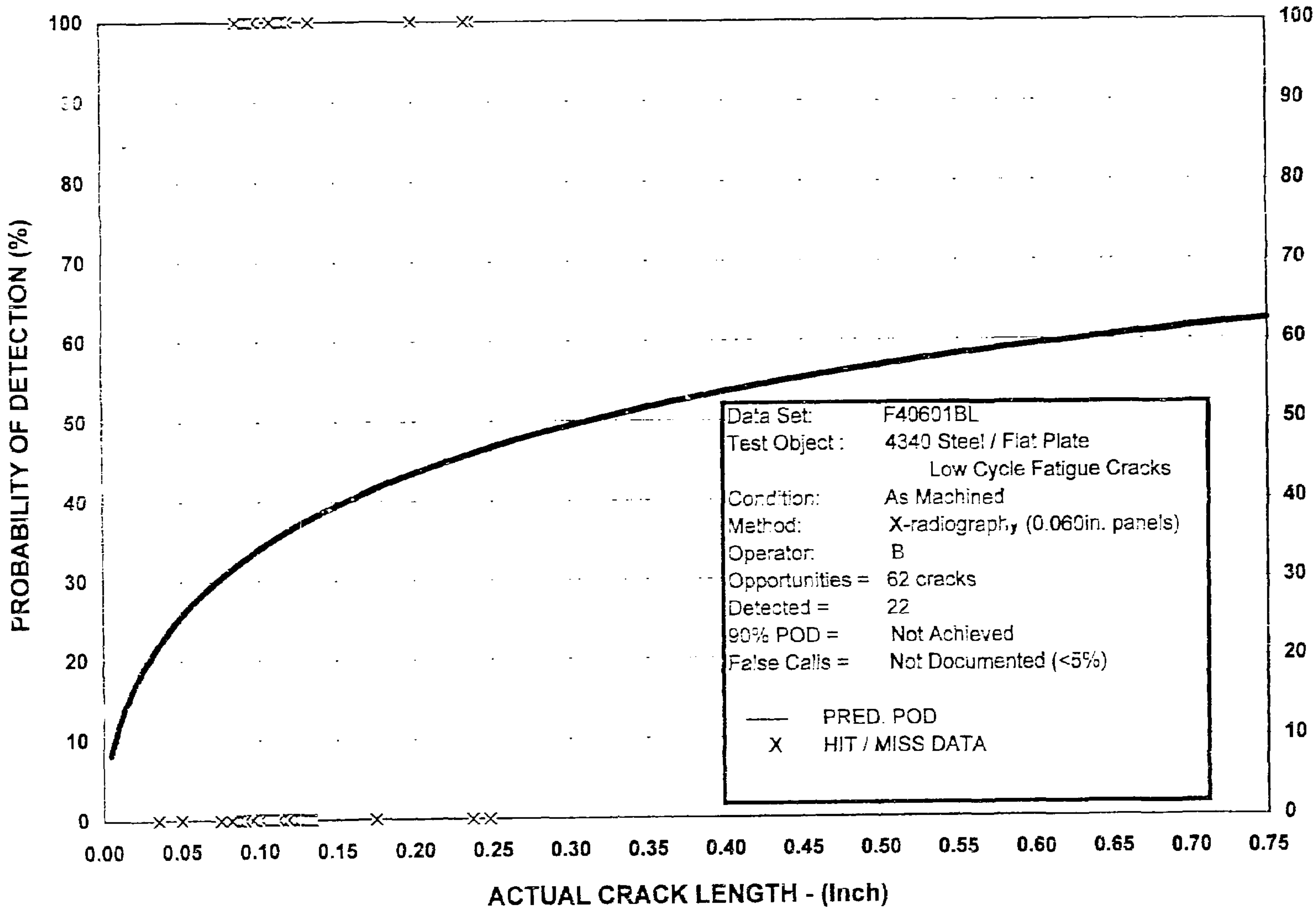
X-RADIOGRAPHIC INSPECTION OF 0.060" STEEL PANELS



F4000(2) X-RADIOGRAPHIC INSPECTION OF 4340 STEEL PANELS

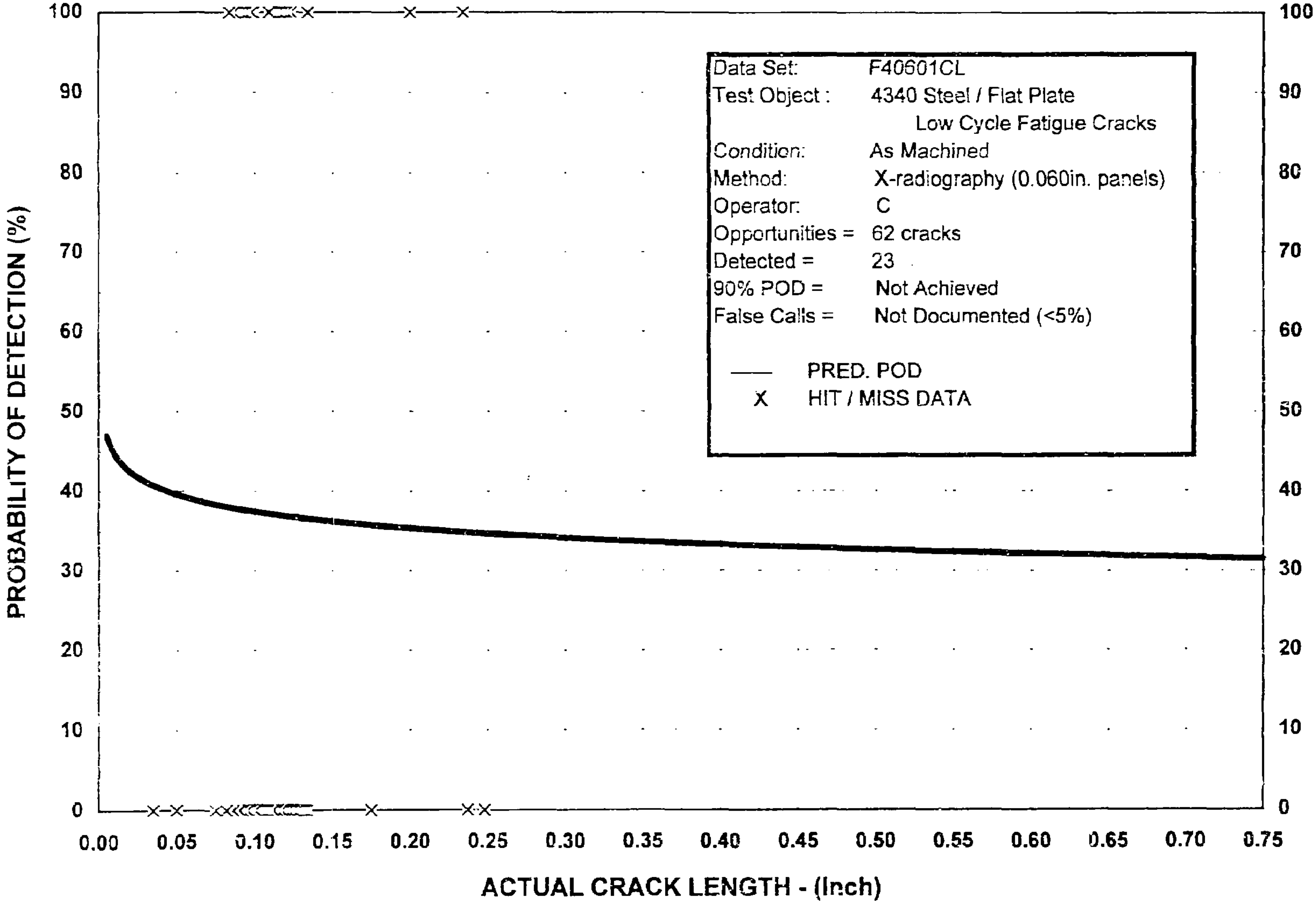
9/96 - F40601AL

F40601AL
AS MACHINED - OPERATOR A



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS
9/96 - F40601BL

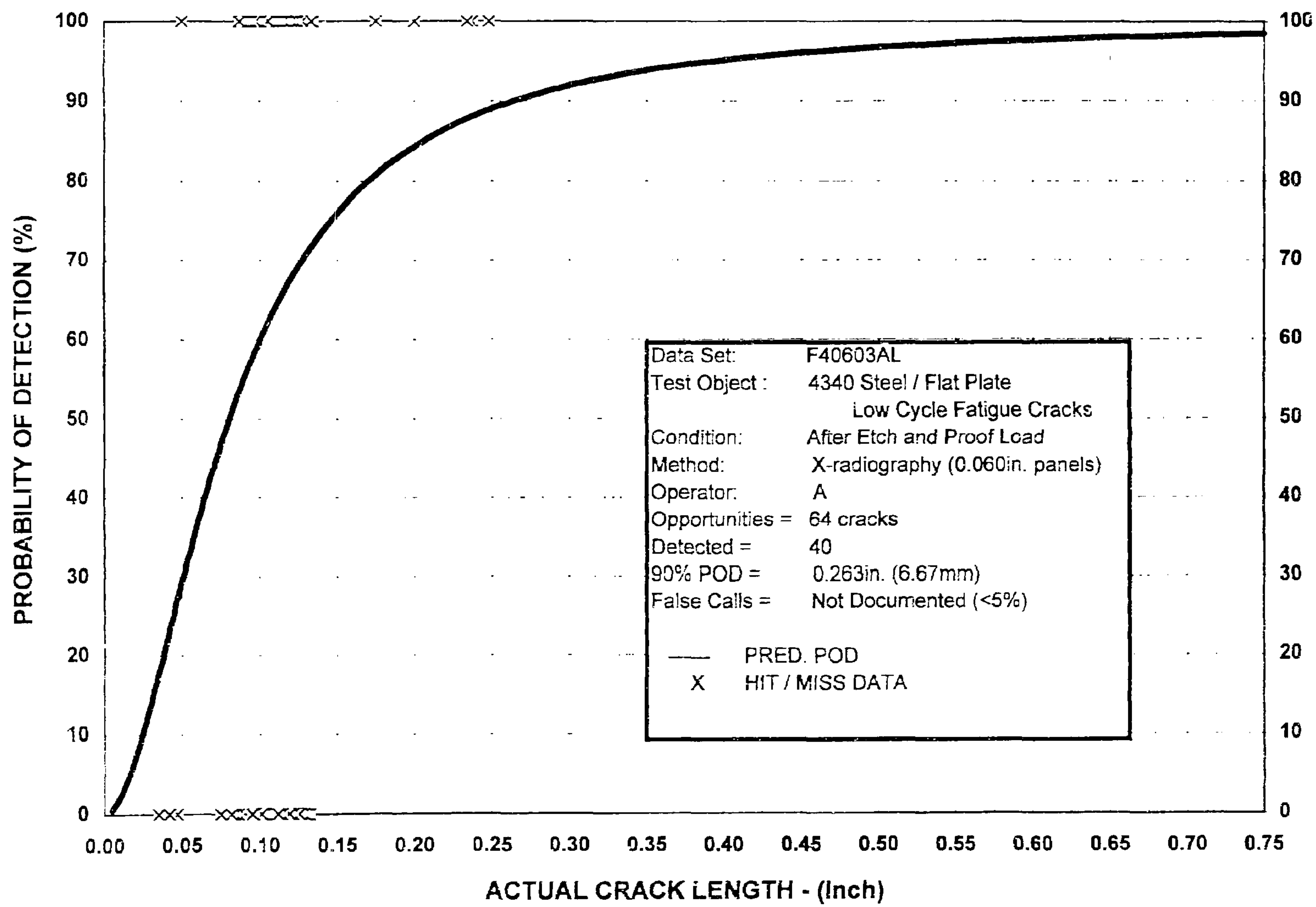
F40601BL
AS MACHINED - OPERATOR B



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS

9/96 - F40601CL

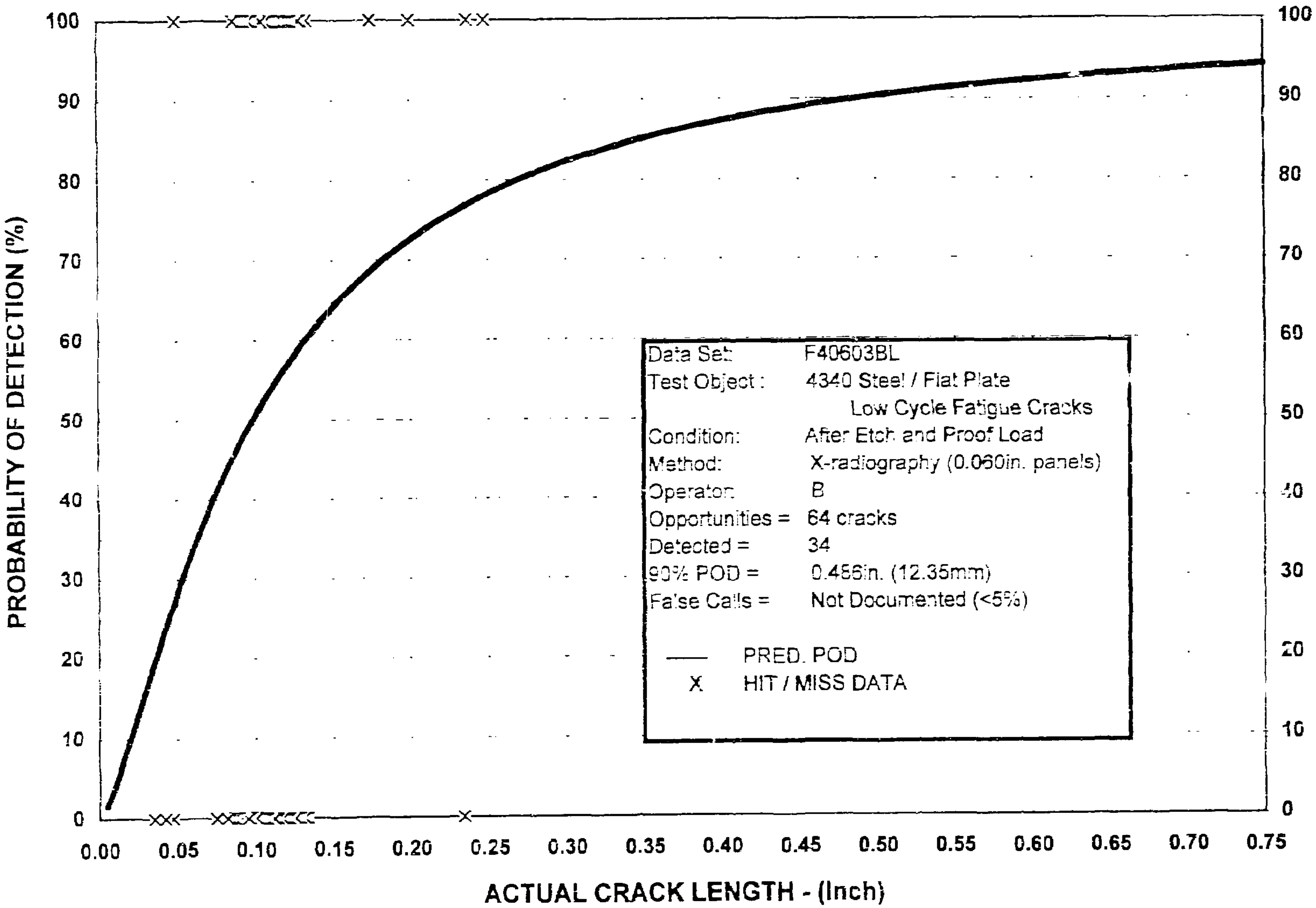
F40601CL
AS MACHINED - OPERATOR C



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS

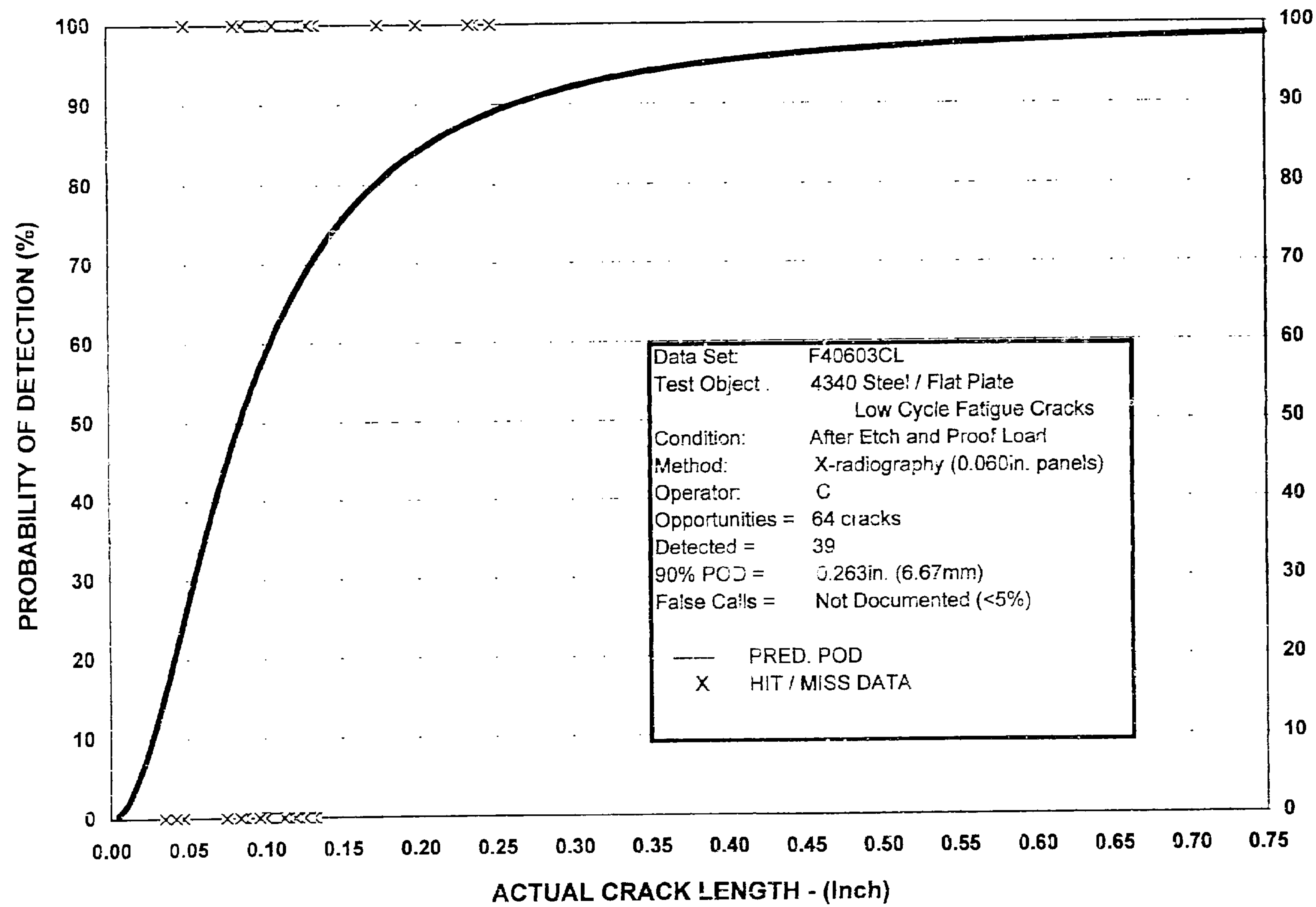
9/96 - F40603AL

F40603AL
AFTER ETCH AND PROOF LOAD - OPERATOR A



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS
9/96 - F40603BL

F40603BL
AFTER ETCH AND PROOF LOAD - OPERATOR B

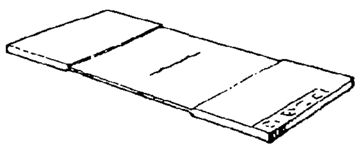


F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS

9/96 - F40603CL

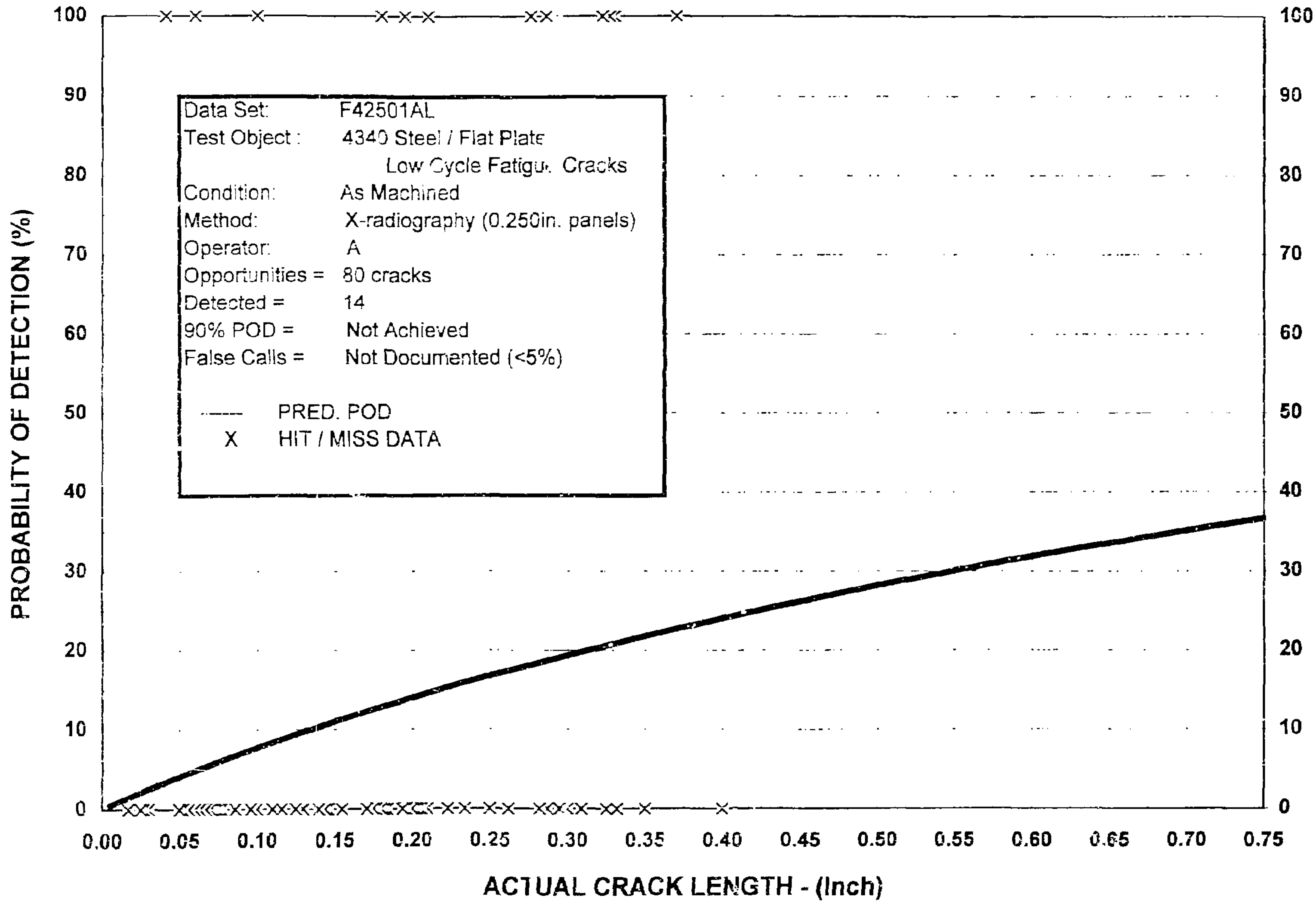
F40603CL
AFTER ETCH AND PROOF LOAD - OPERATOR C

F4250(2)L	DATA SET DESCRIPTION
METHOD:	X-Radiographic Inspection by CRACK LENGTH - 0.250" panel thickness
TEST OBJECT TYPE:	Flat Plate - 6 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	X-radiographic inspection: Kodak Type M Film; Automatic Processing; Exposure optimized to test specimens
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation. growth in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Steel - 4340
TEST OBJECT THICKNESS:	0.250 inch nominal
TEST OBJECT CONDITION:	F42501,"As Machined": F42503,"After Etch and Proof Loading"
SURFACE FINISH:	125 RMS - representative of good machining practices
APPLICATION:	Manual Processing / Manual Inspection (Wet Horizontal / Uresco 228 fluorescent particles)
DATA SET IDENTIFIER:	F42501-A,B,C; F42503-A,B,C
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	112 Cracks -Variation in the number inspected during each sequence
DETECTED:	F42501 - A = 14/80, B= 17/80, C= 11/80; F42503 - A= 49/112, B= 48/112, C= 51/112
FALSE CALLS:	Not reported (<5%)
REFERENCE:	NASA CR-151098, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., Thomas L. Tedrow, and Steve J. Mullen, Detection of Tightly Closed Flaws by Nondestructive Testing Methods in Steel and Titanium, November, 1976.
DATE:	July 1975 - September 1976
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics & Space Administration (NASA) Space Shuttle design and was used as a basis for design / acceptance criteria. Flaws were induced in 45 panels (both sides). Fifteen (15) blank panels were included for a total of 60 panels The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.



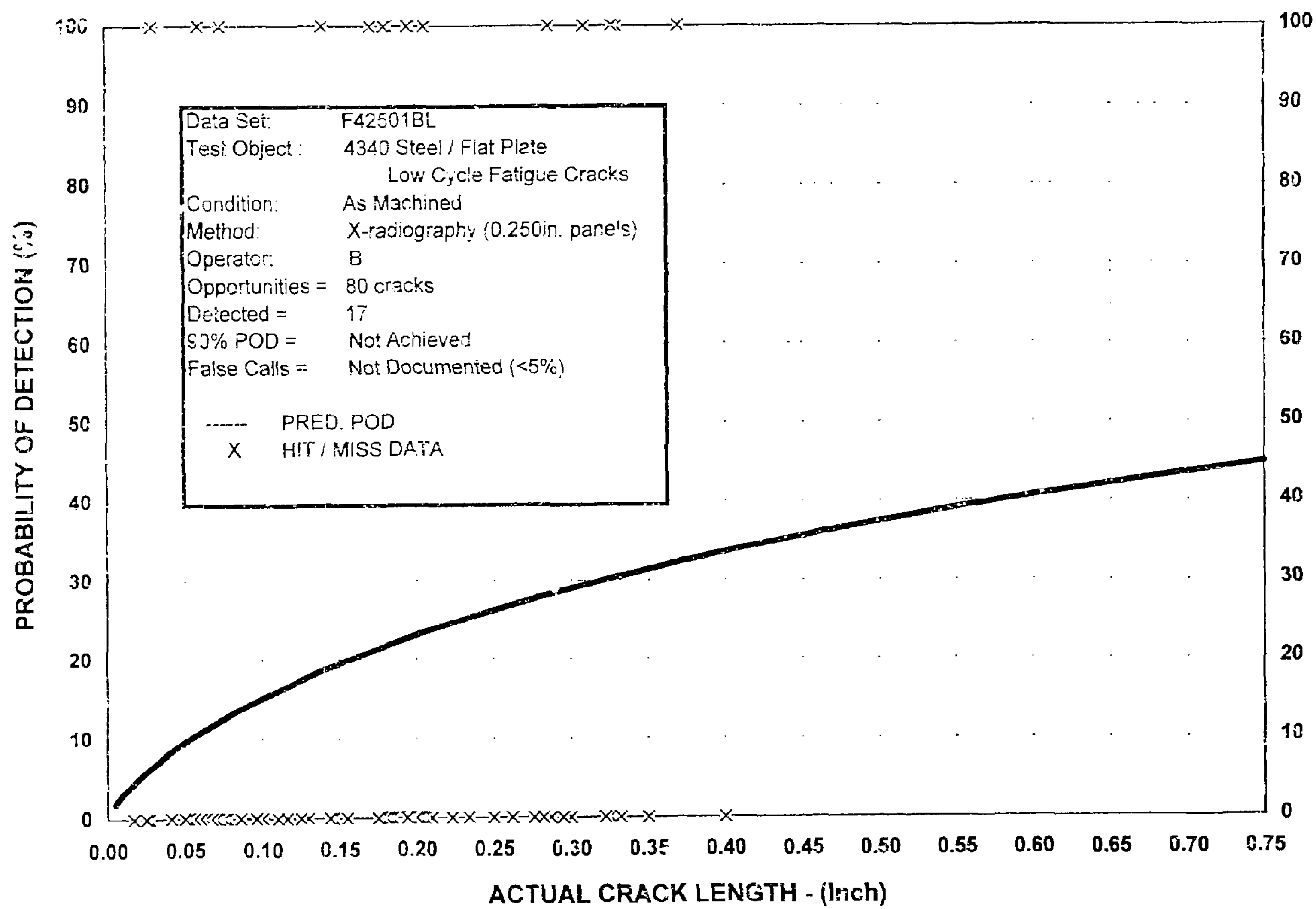
CRACK LENGTH		
90% POD	"AS MACHINED"	"AFTER PROOF"
	A= Not Achieved	A= Not Achieved
	B= Not Achieved	B= 0.658in (16.72mm)
	C= Not Achieved)	C= 0.571in. (14.5mm)

X-RADIOGRAPHIC INSPECTION OF
0.250" STEEL PANELS



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS (0.250")
9/96 - F42501AL

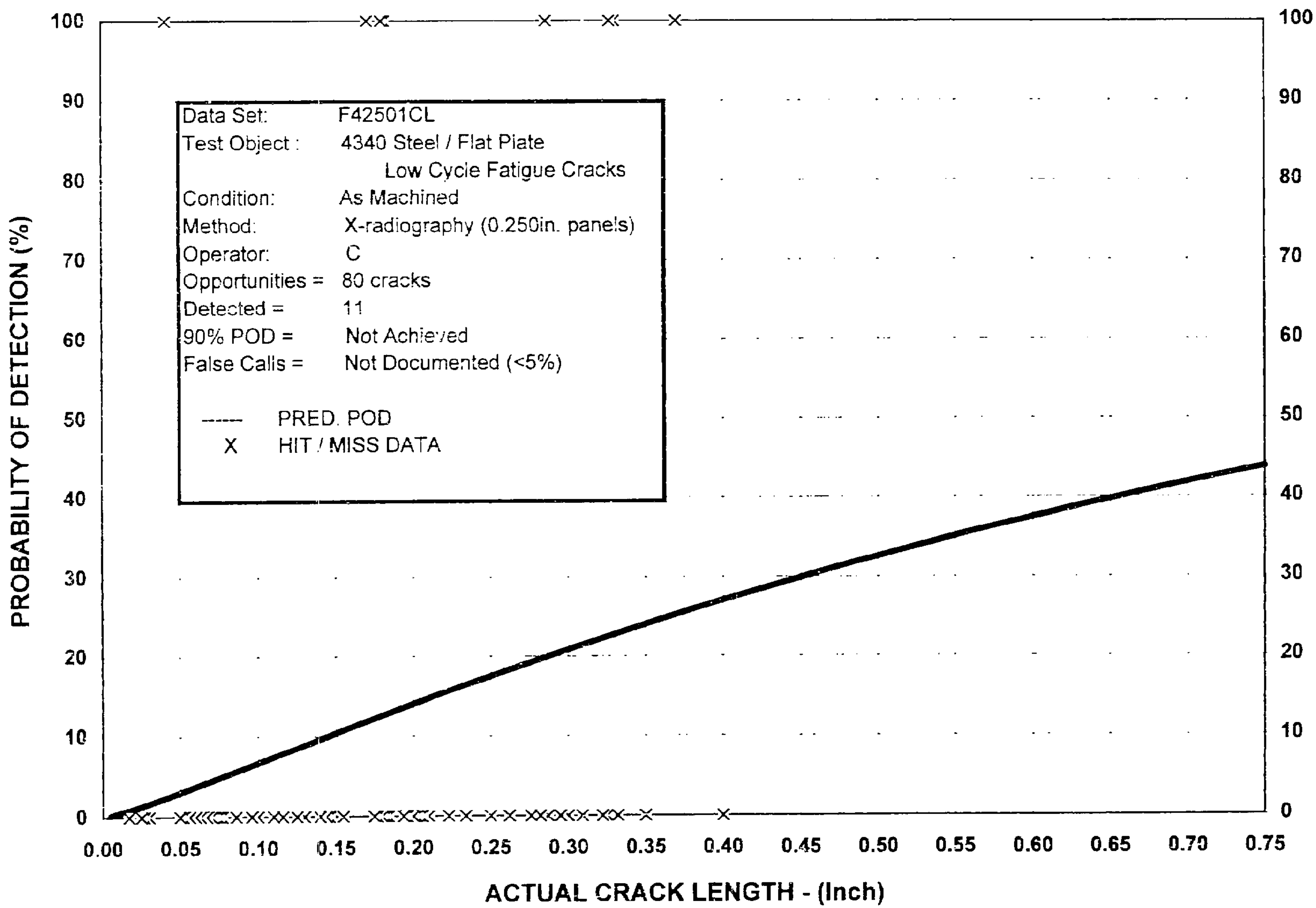
F42501AL
AS MACHINED - OPERATOR A



F4000(2) X-RADIOGRAPHIC INSPECTION OF 4340 STEEL PANELS (0.250")

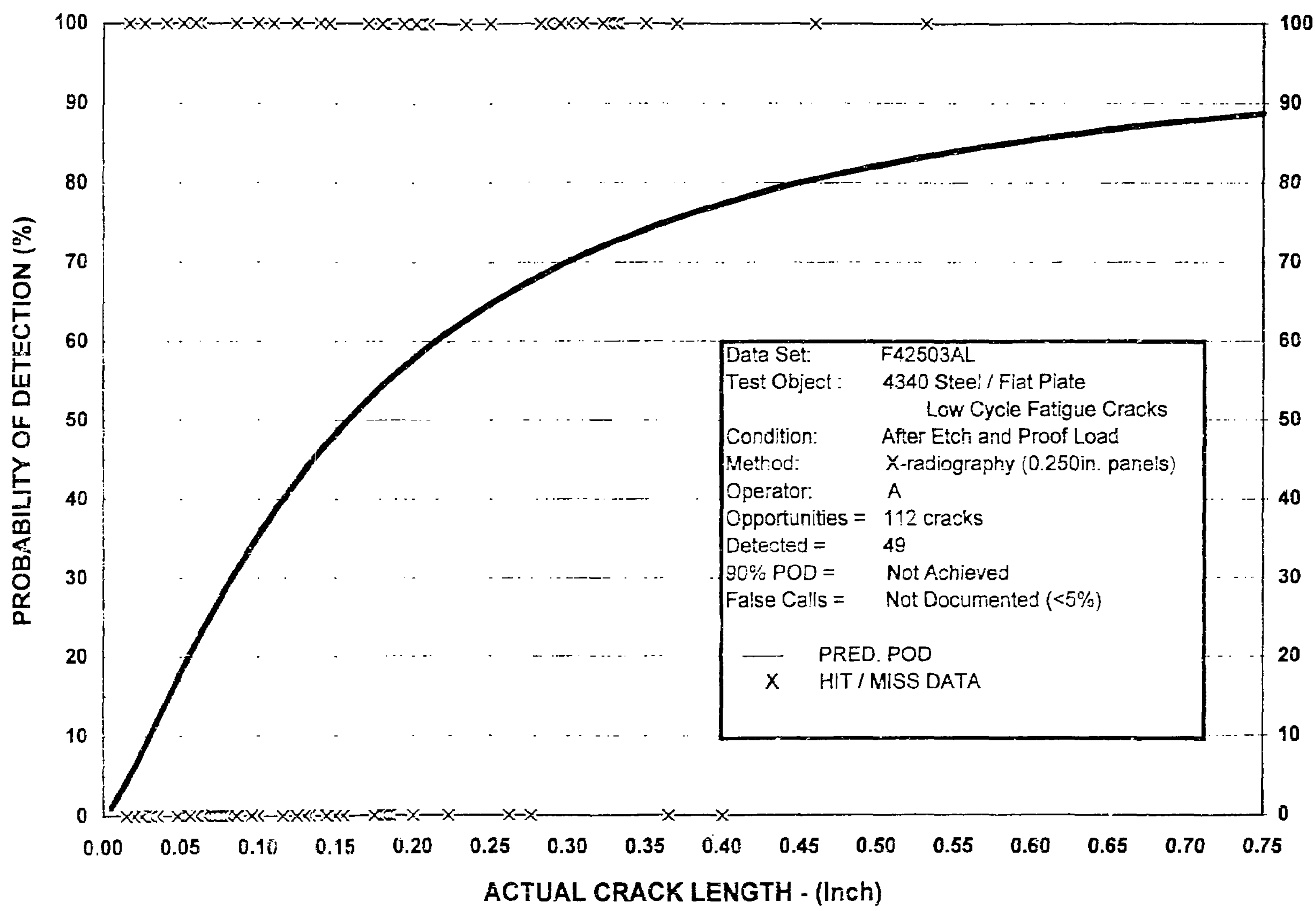
9/96 - F42501BAL

F42501BL
AS MACHINED - OPERATOR B



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS (0.250")
9/96 - F42501CL

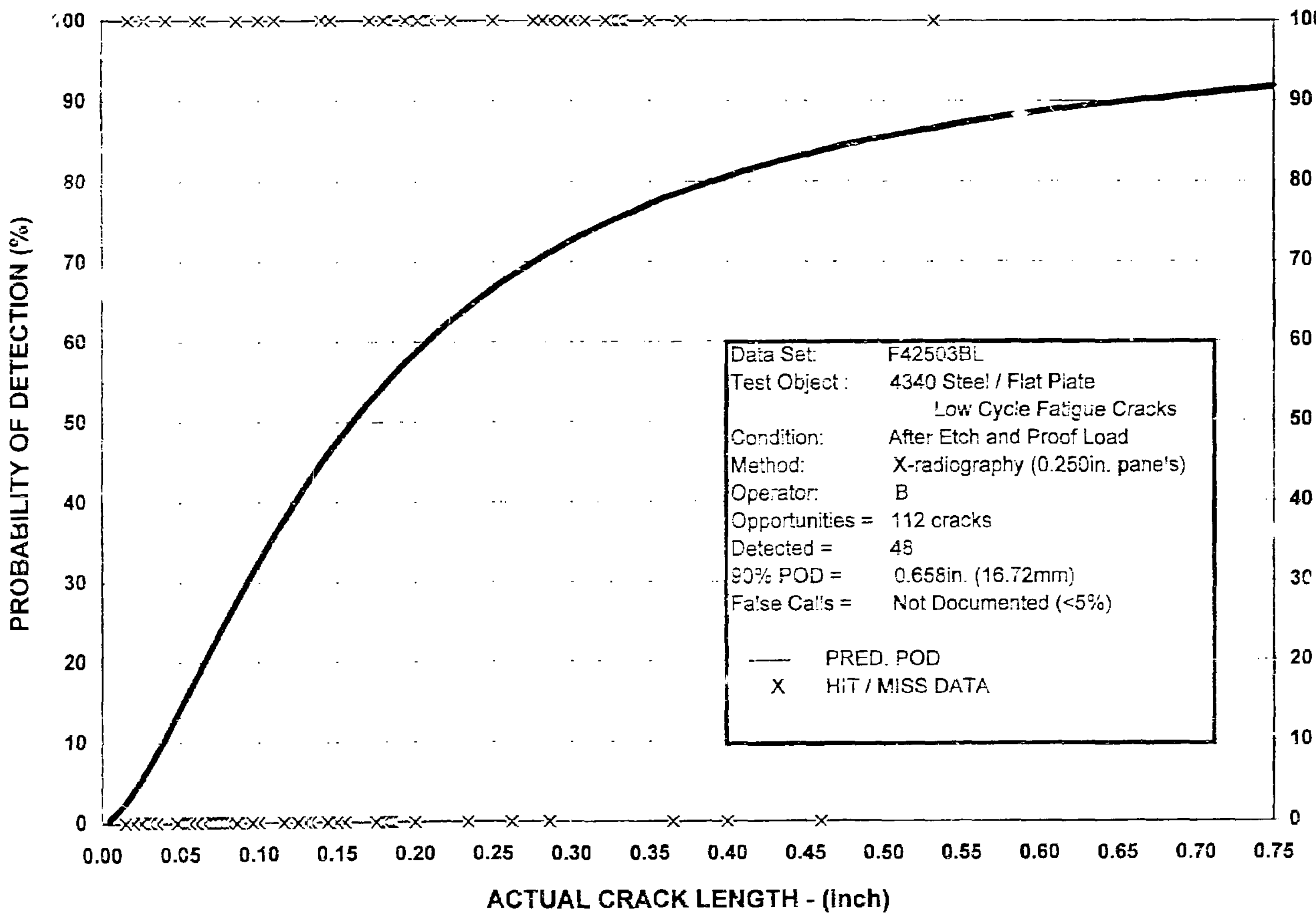
F42501CL
AS MACHINED - OPERATOR C



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS (0250")

9/96 - F42503AL

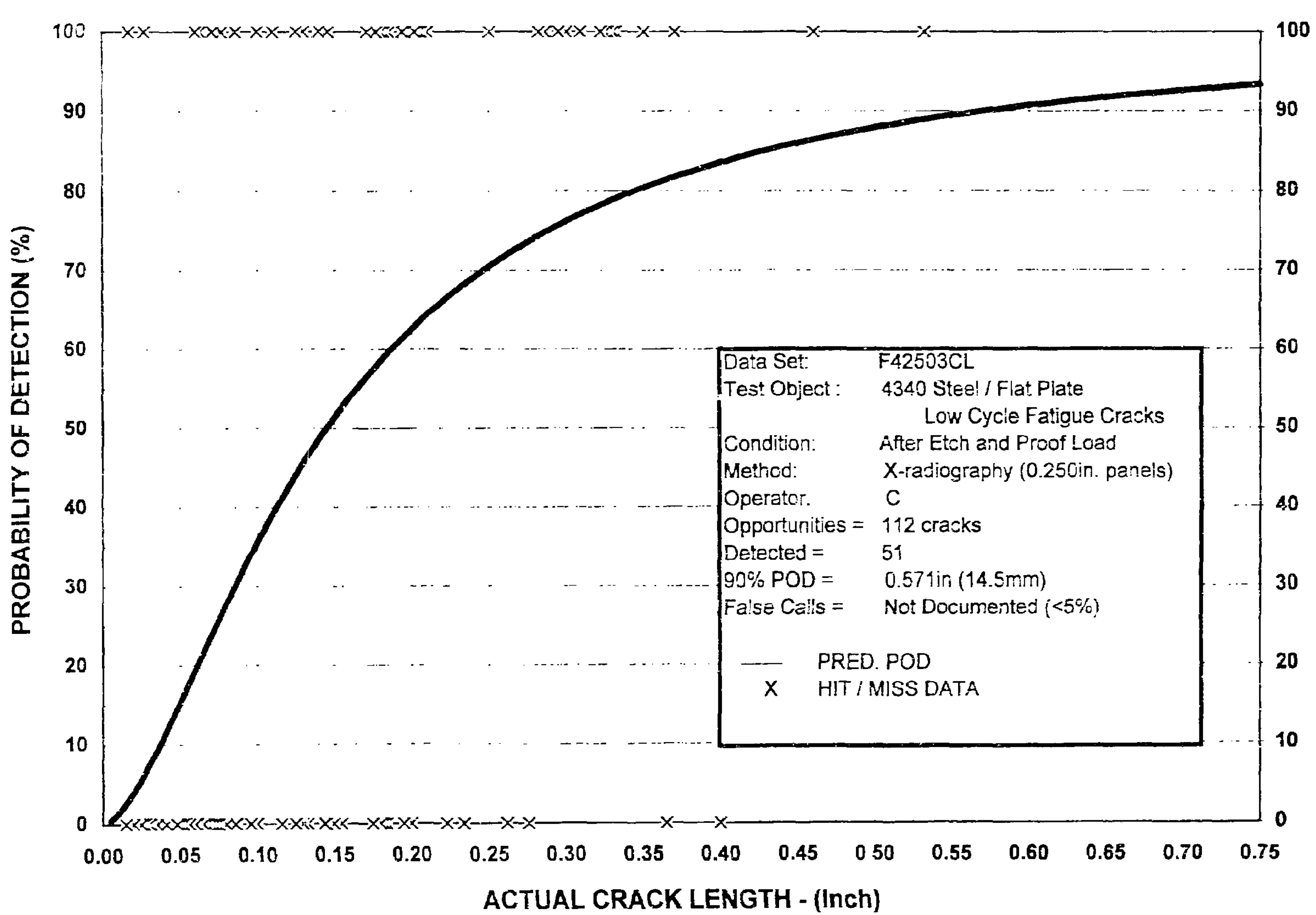
F42503AL
AFTER ETCH AND PROOF LOAD - OPERATOR A



F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS (0250")

9/96 - F42503BL

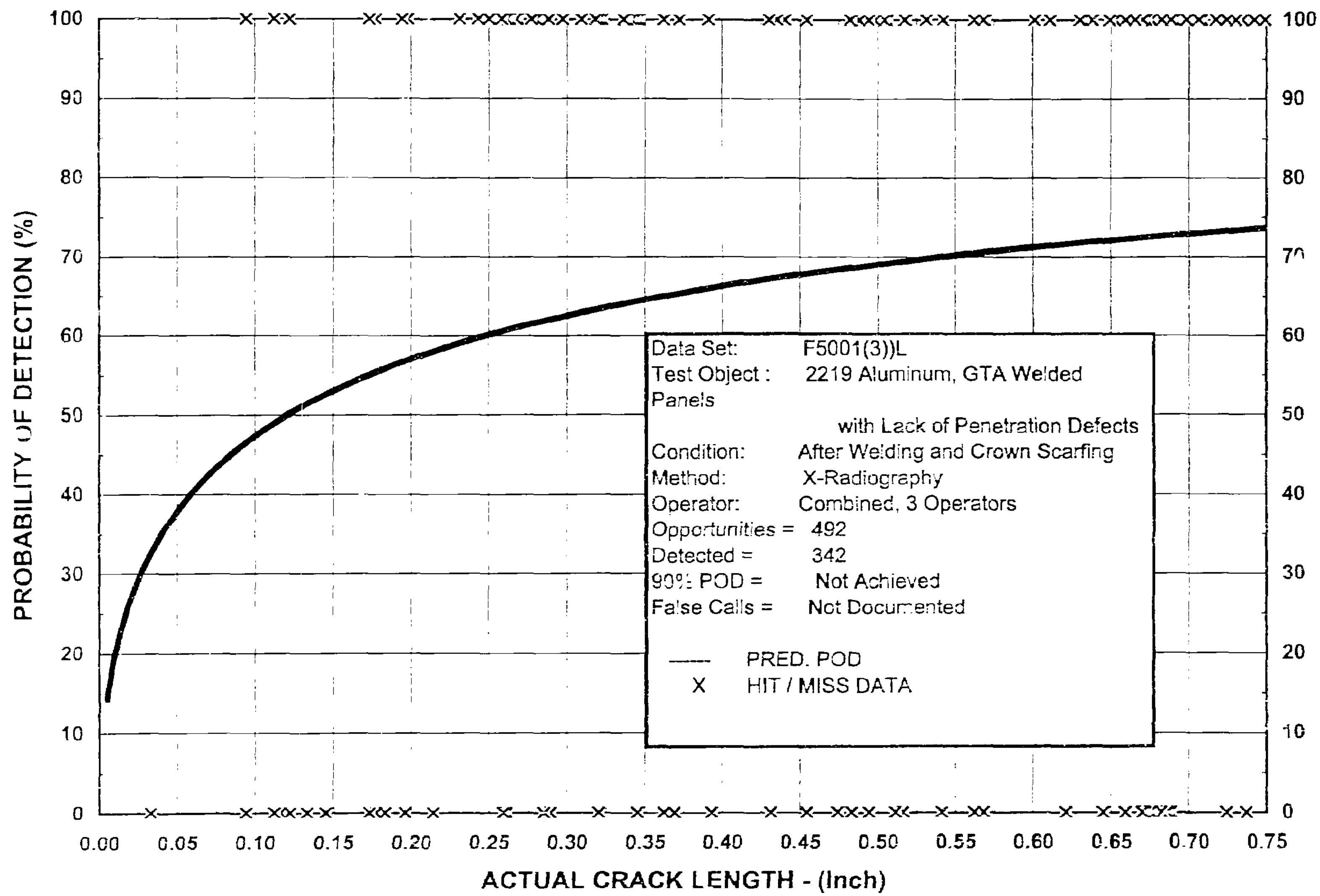
F42503BL
AFTER ETCH AND PROOF LOAD - OPERATOR B



F42503CL
AFTER ETCH AND PROOF LOAD - OPERATOR C

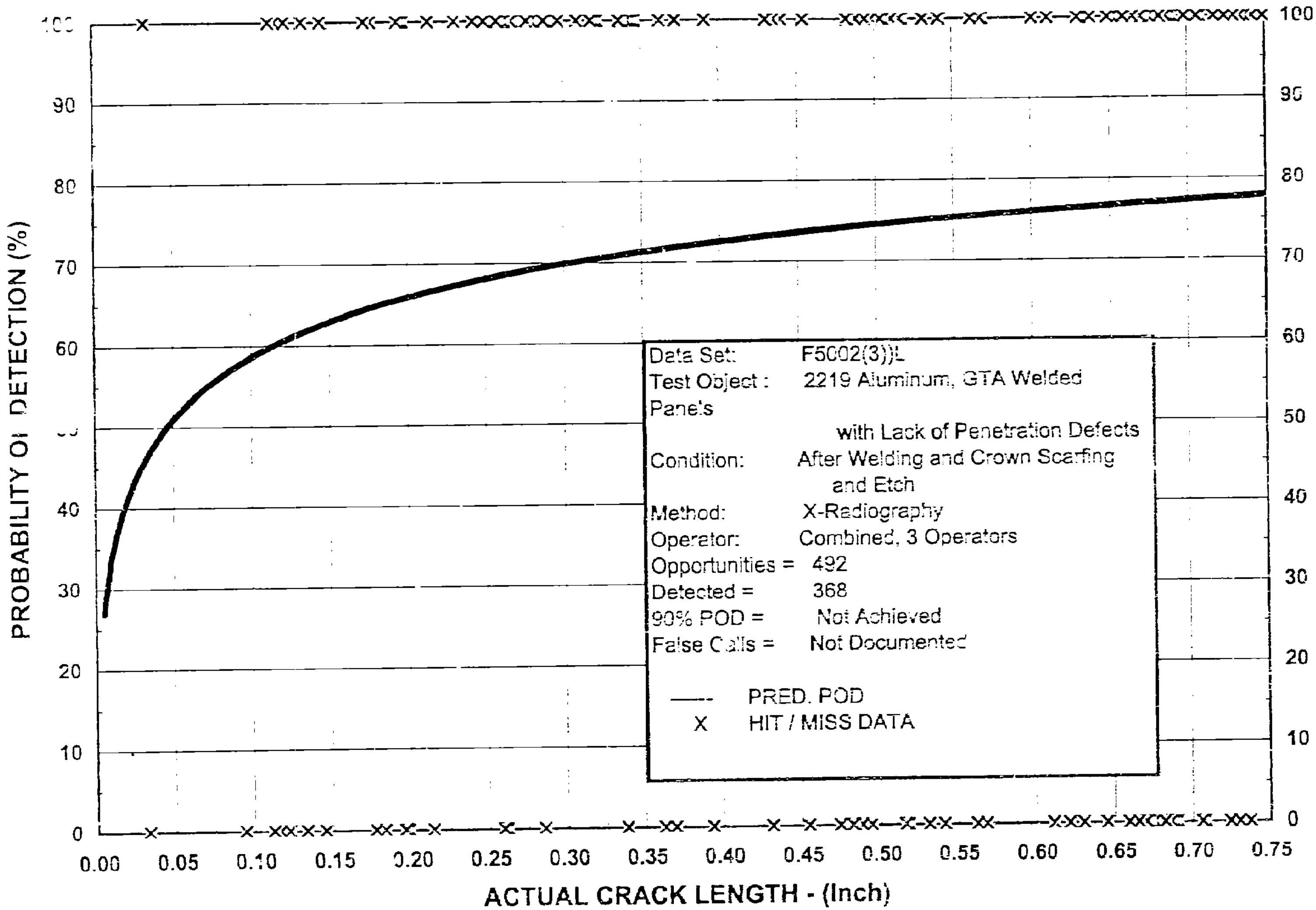
F4000(2) X-RADIOGRAPHIC INSPECTION
OF 4340 STEEL PANELS (0250")
9/96 - F42503CL

F5000(3)L,D	**DATA SET DESCRIPTION**
METHOD:	X-radiographic Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. One pass from each panel surface.
NDE PROCEDURE:	Probes were 100 kHz, 0.063 in. core for 0.125 inch and 20 kHz for the 0.500 inch panels.
ARTIFACT TYPE:	Lack of Penetration (LOP) defects / cracks, produced by the two pass weld process
ARTIFACT SHAPE:	Lune shapes with target lengths of 0.250, .500 and 1.00 inch and apex depths of 0.030 to 0.100 inch
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and surface scarfed"; -02,"After Etch"; -03, " After Proof Loading.
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Machine raster scan with threshold gating.
DATA SET IDENTIFIER:	F5001(3)L,D; F5002(3)L,D; F5003(3)L,D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	166 Cracks / 499 opportunities. (Some defects / crack were lost during proof loading)
DETECTED:	-01(3)D,L = 463; -02(3)D,L = 338 ; -03(3)D,L = 448 (Combined data for 3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **<u>The Detection of Tightly Closed Flaws by Nondestructive Testing Methods</u>**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	166 flaws were induced in 93 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD Length - "AS PRODUCED" "AFTER ETCH" "AFTER PROOF LOADING"
	-01L A= Not Achieved -02 L, A= Not Achieved -03 L, A= No Test
	-01D A= 0.149 in. -02 D, A= Not Achieved -03 D, A= No Test
	Authors Note: The test set was not optimized for the X-radiographic inspection method, but provides a good assessment of the effects of etching and proof loading on a "lack of penetration" weld defect. After proof, most of the defects were detected.
Test Specimen Descriptions	
in AA000(3)L, Page 2	



F5001(3)L
11/97 -F5001(3)L

X-Radiographic Inspection - 3 Operators
2219 Alum inum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing

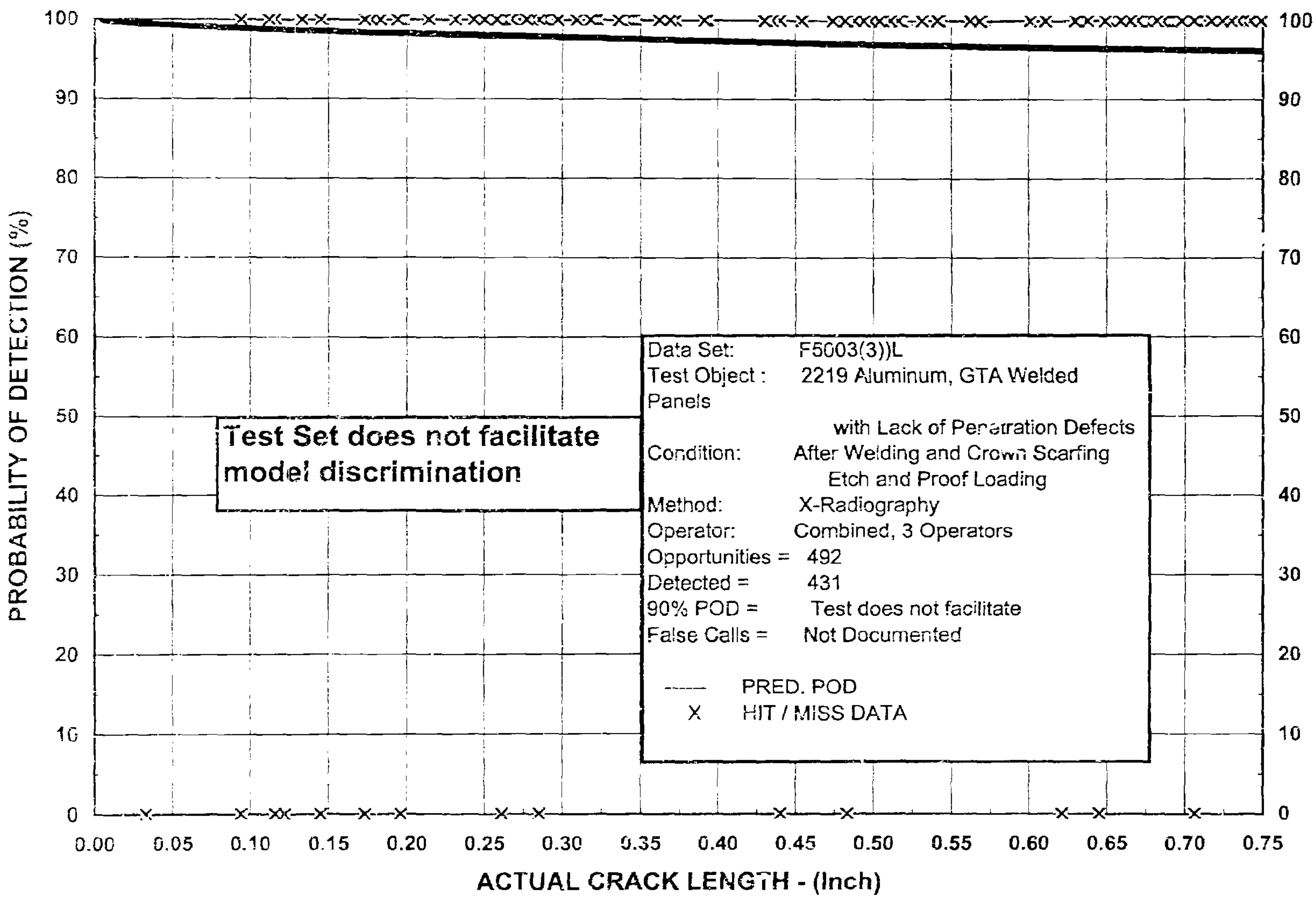


X-Radiographic Inspection - 3 Operators

2219 Alum inum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etch

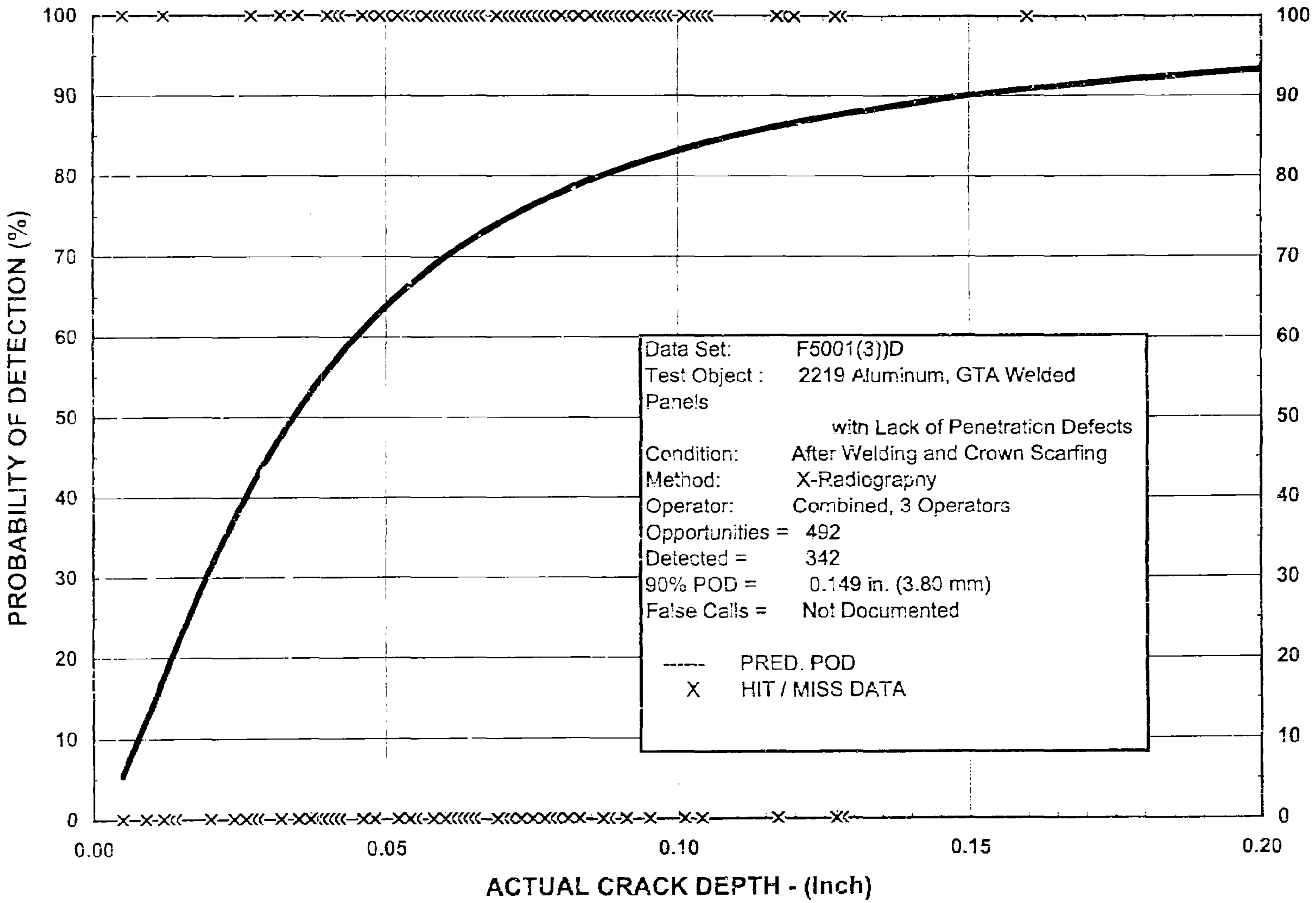
F5002(3)L

11/97 -F5002(3)L



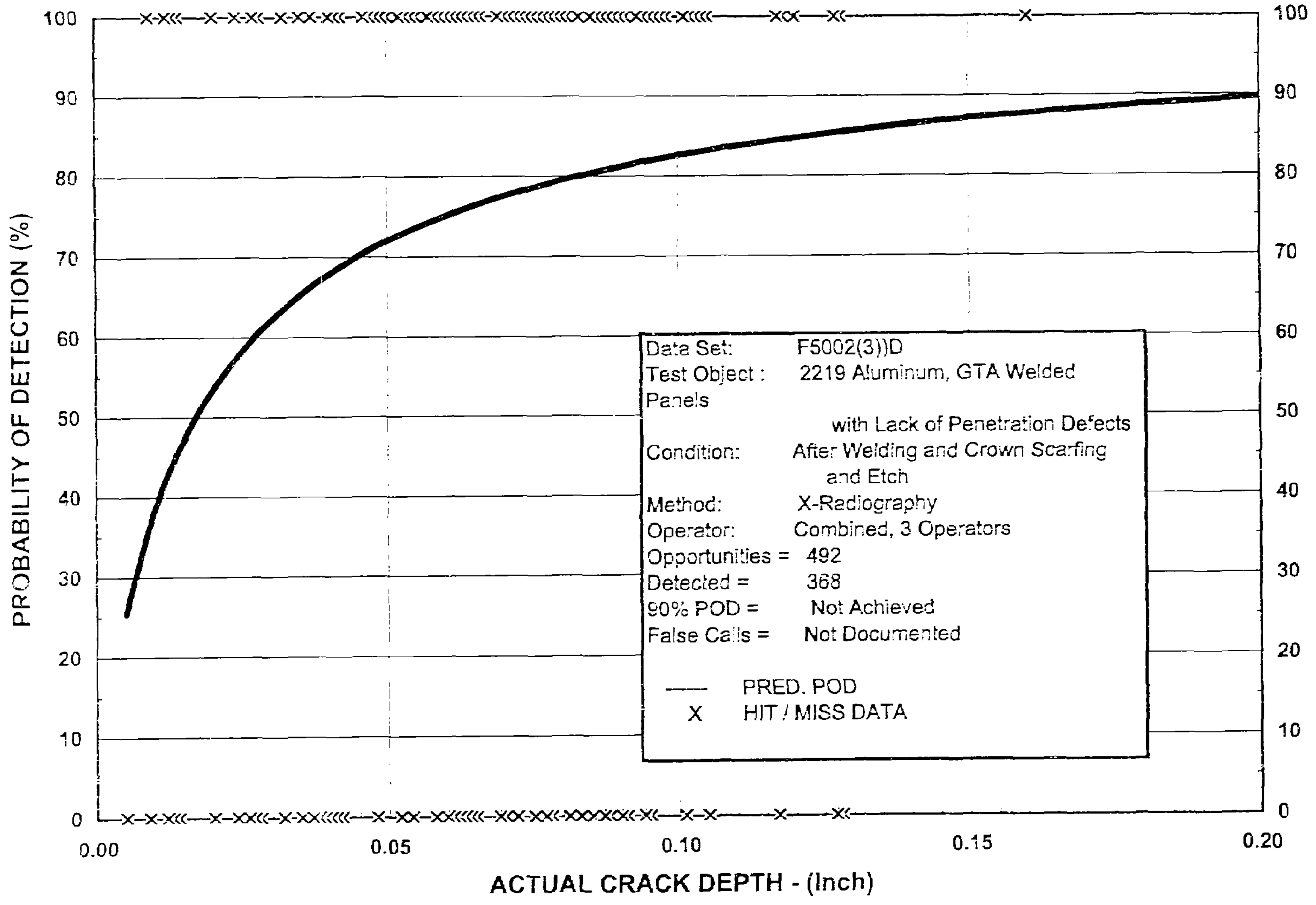
X-Radiographic Inspection - 3 Operators
2219 Alum inum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing, Etching and Proof Loading

F5003(3)L
11/97 -F5003(3)L



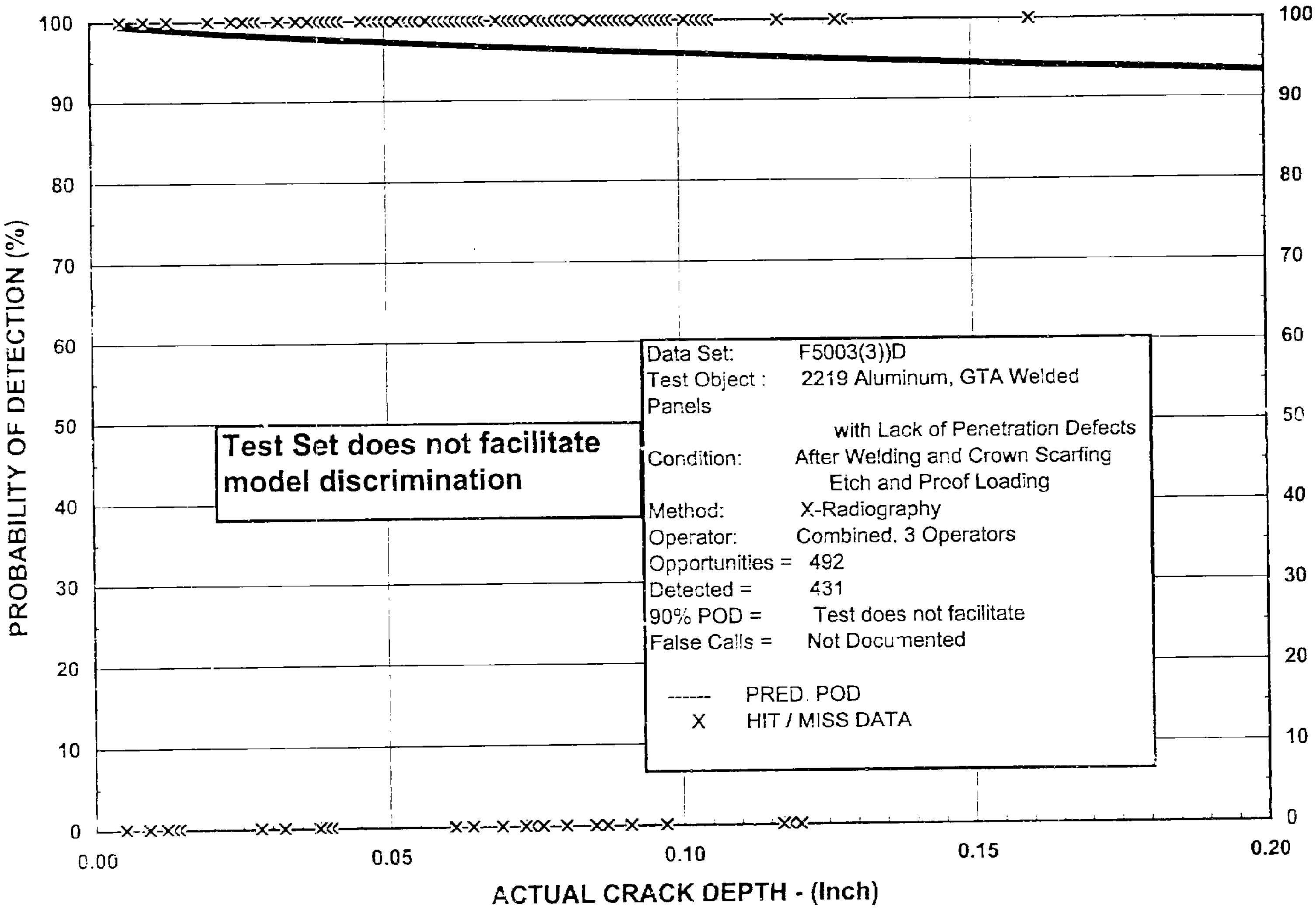
F5001(3)D
11/97 -F5001(3)D

X-Radiographic Inspection - 3 Operators
2219 Alum inum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing

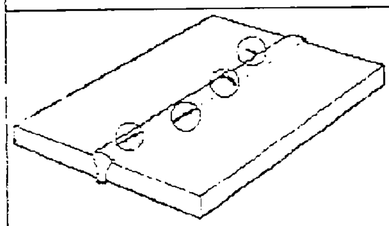


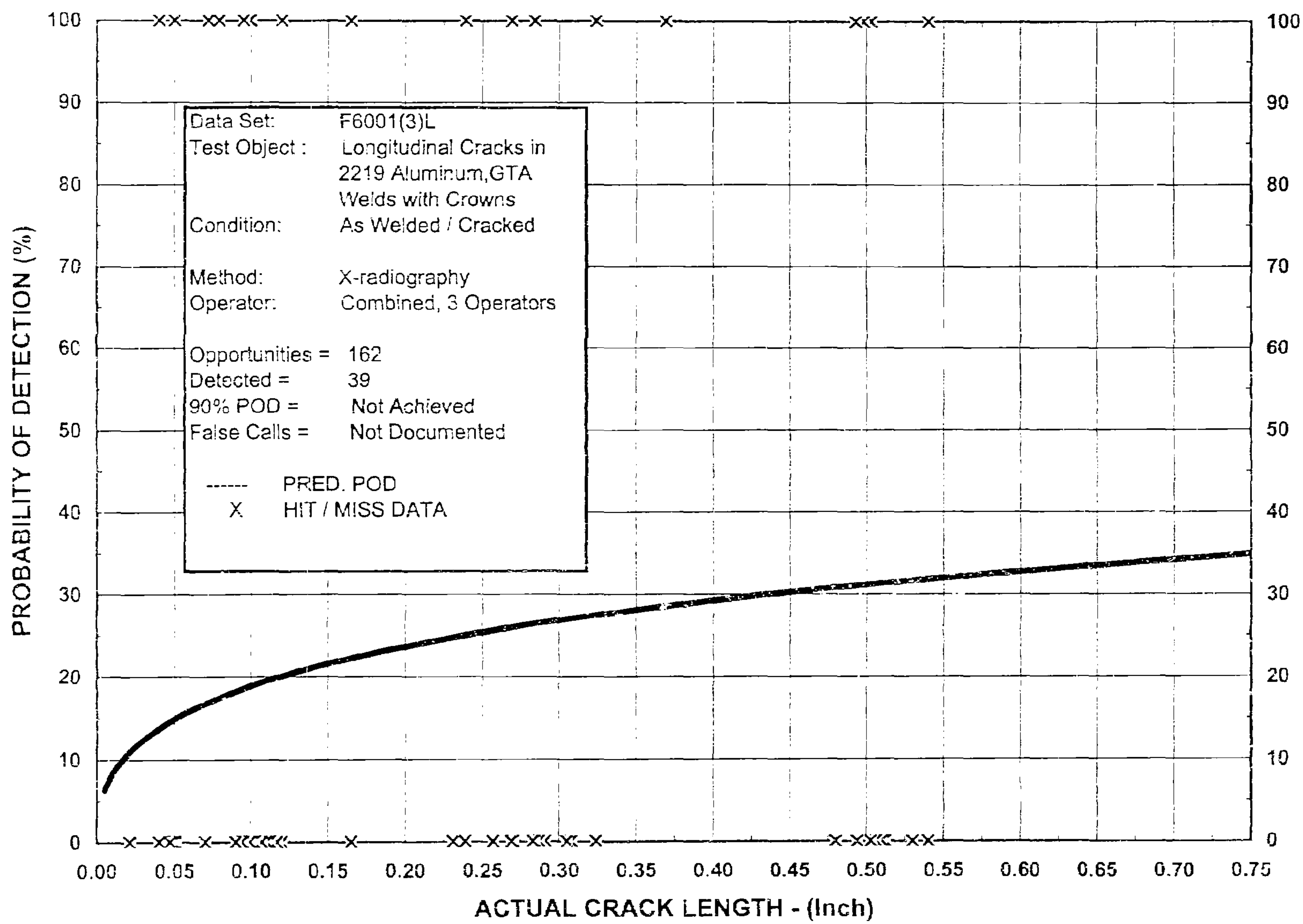
F5002(3)D
11/97 -F5002(3)D

X-Radiographic Inspection - 3 Operators
2219 Alum inum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing and Etch



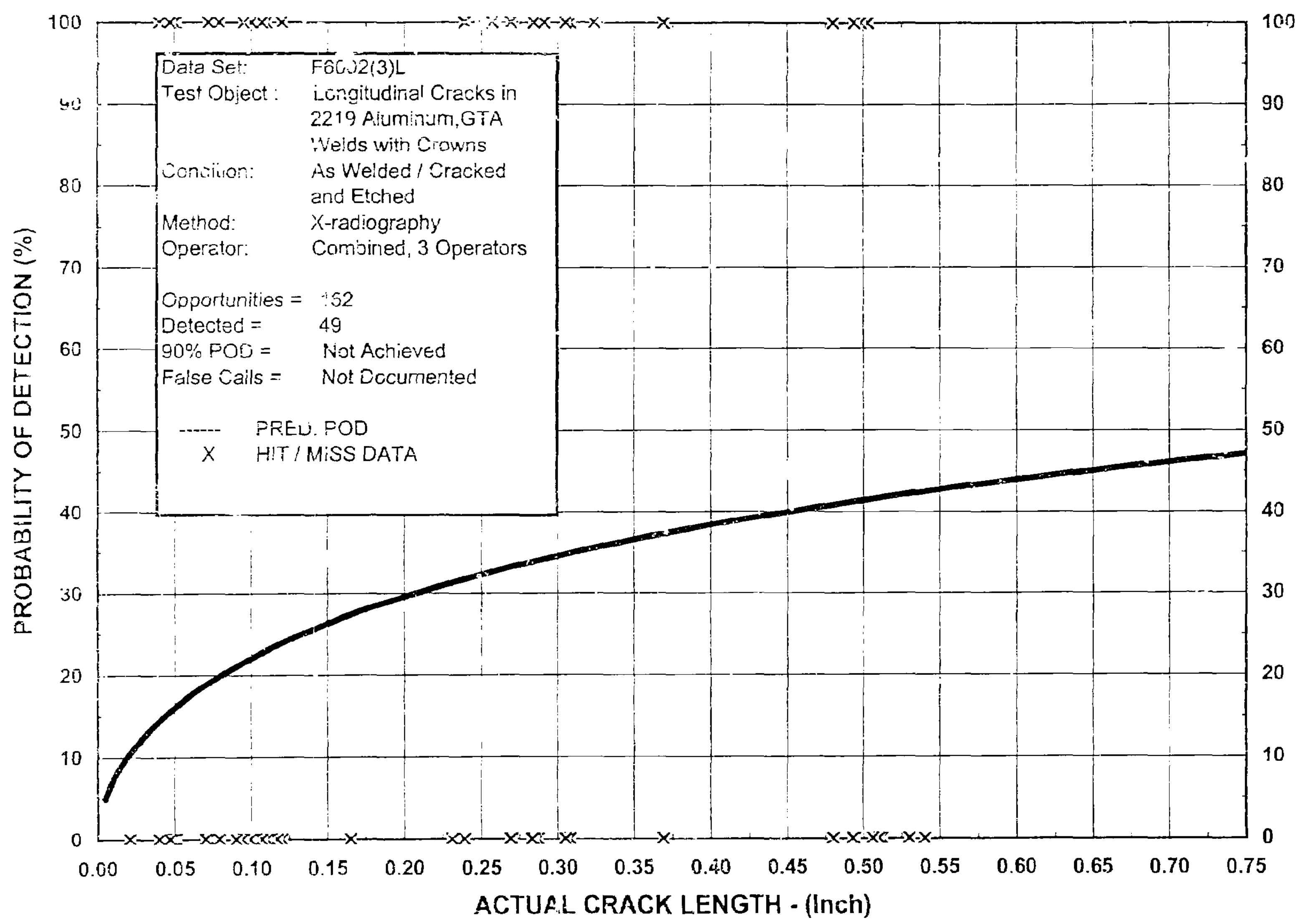
X-Radiographic Inspection - 3 Operators
2219 Aluminum, GTA Welded Panels with Lack of Penetration, After Weld Crown Scarfing, Etching and Proof Loading

F6000(3)L,D	**DATA SET DESCRIPTION - LONGITUDINAL WELDS WITH CROWNS**
METHOD:	X-radiographic inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	45 and 70 KV; 20 ma; 48" FFD;Time: 1 1/2 to 2 1/2 min.(Thickness); Kodak Type M, Automatic Processing
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and Scarfed"; -02, "After Etch"; and -03, "After Proof Loading".
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Exposure time adjusted with thickness to produce a 3.0 film density and a 2T penetrameter image
DATA SET IDENTIFIER:	F6001(3)L/D; F6002(3)L/D; F6003(3)L/D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	162 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)D/L = 39; -02(3)D/L = 49; -03(3)D/L= 60
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	166 surface open flaws were induced in 63 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED"; "AFTER ETCH"; "AFTER PROOF";
	-01 L. A = Not Achieved -02 L, A= Not Achieved -03 L, A= Not Achieved
	-01 D, A= Not Achieved -02 D, A= Not Achieved -03 D, A= Not Achieved
Test Specimen Descriptions	**Authors Note:** The test set was not optimized for the X-radiographic inspection method, but provides a good assessment of the effects of etching and proof loading on a tight fatigue crack defect.
in AB000(3)L, Page 2	



F6001(3)L
6/97 -F6001(3)L

X-Radiography- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed

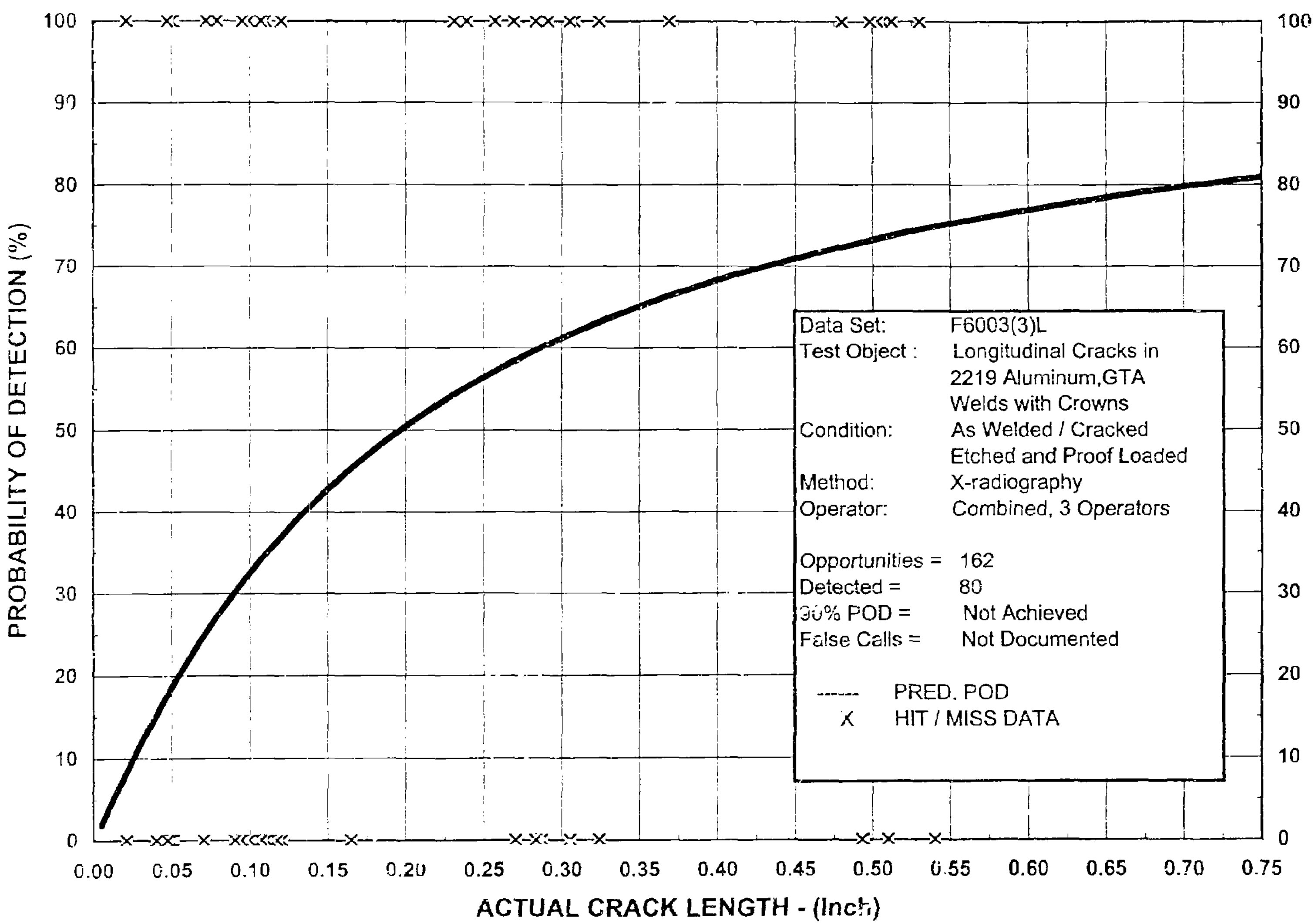


X-Radiography- 3 Operators

Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched

F6002(3)L

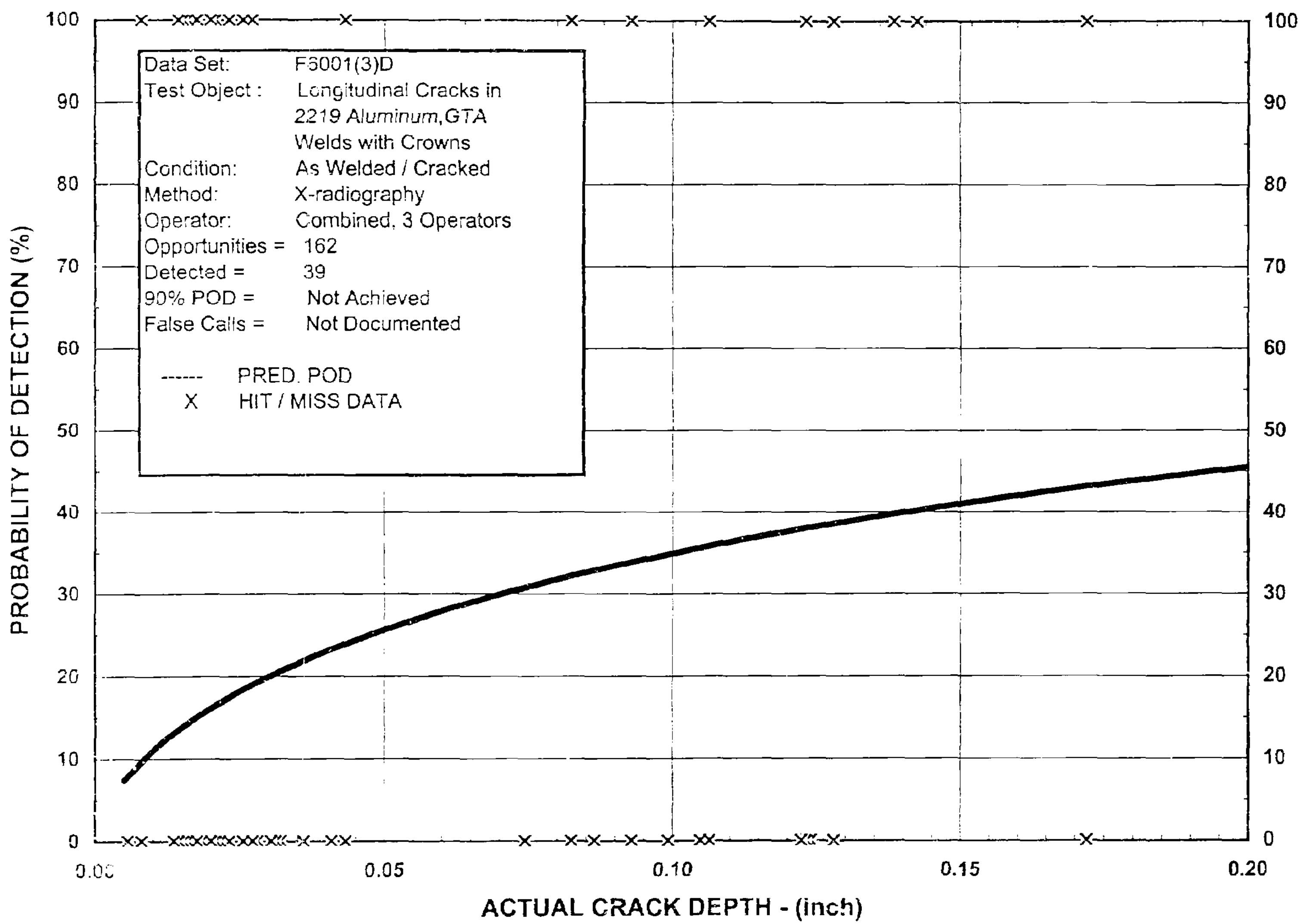
6/97 -F6002(3)L



F6003(3)L

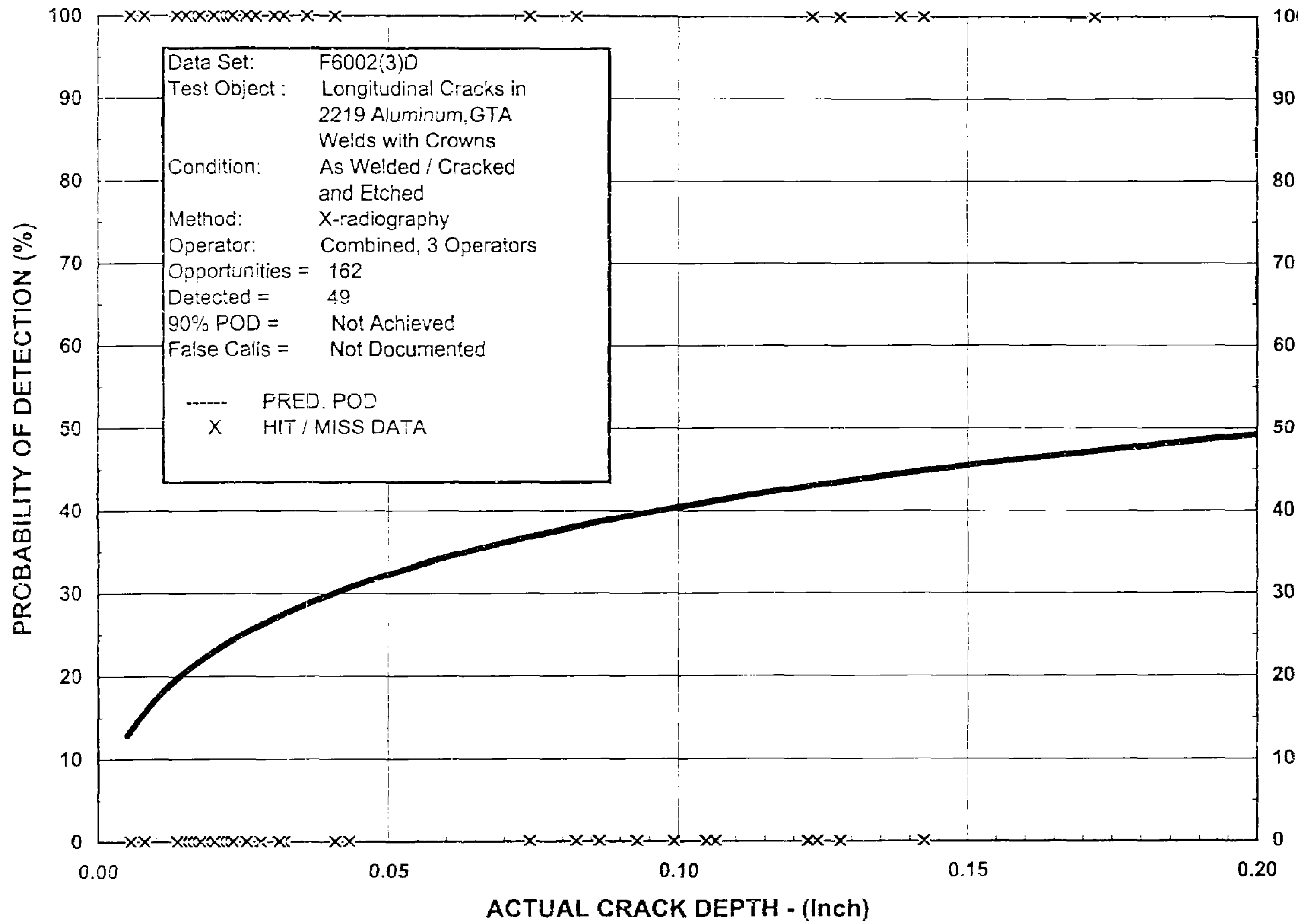
6/97 -F6003(3)L

X-Radiography- 3 Operators Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Proof Loaded



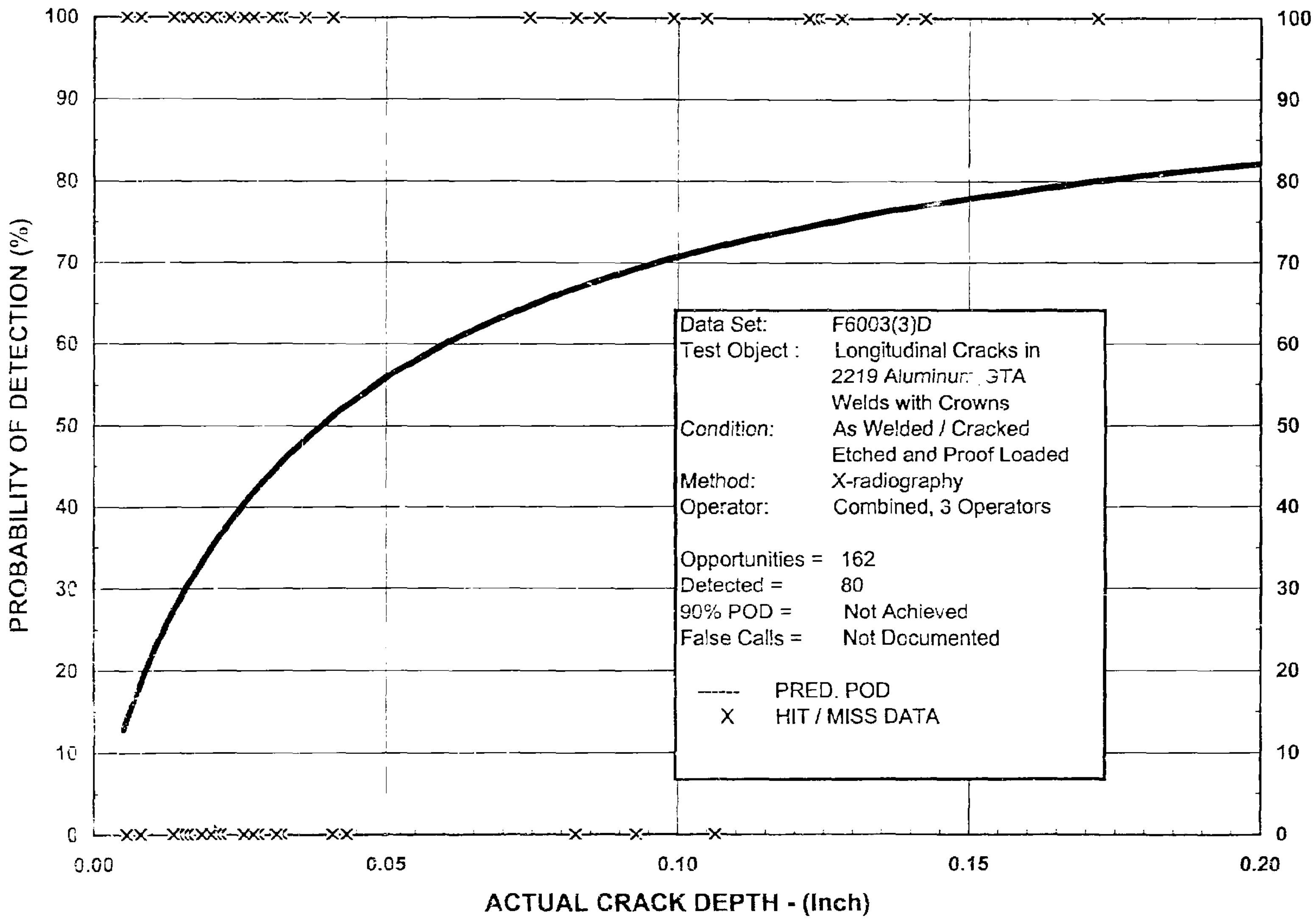
F6001(3)D
6/97 -F6001(3)D

X-Radiography- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



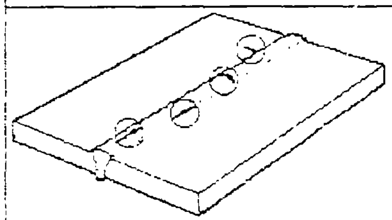
F6002(3)D
6/97 -F6002(3)D

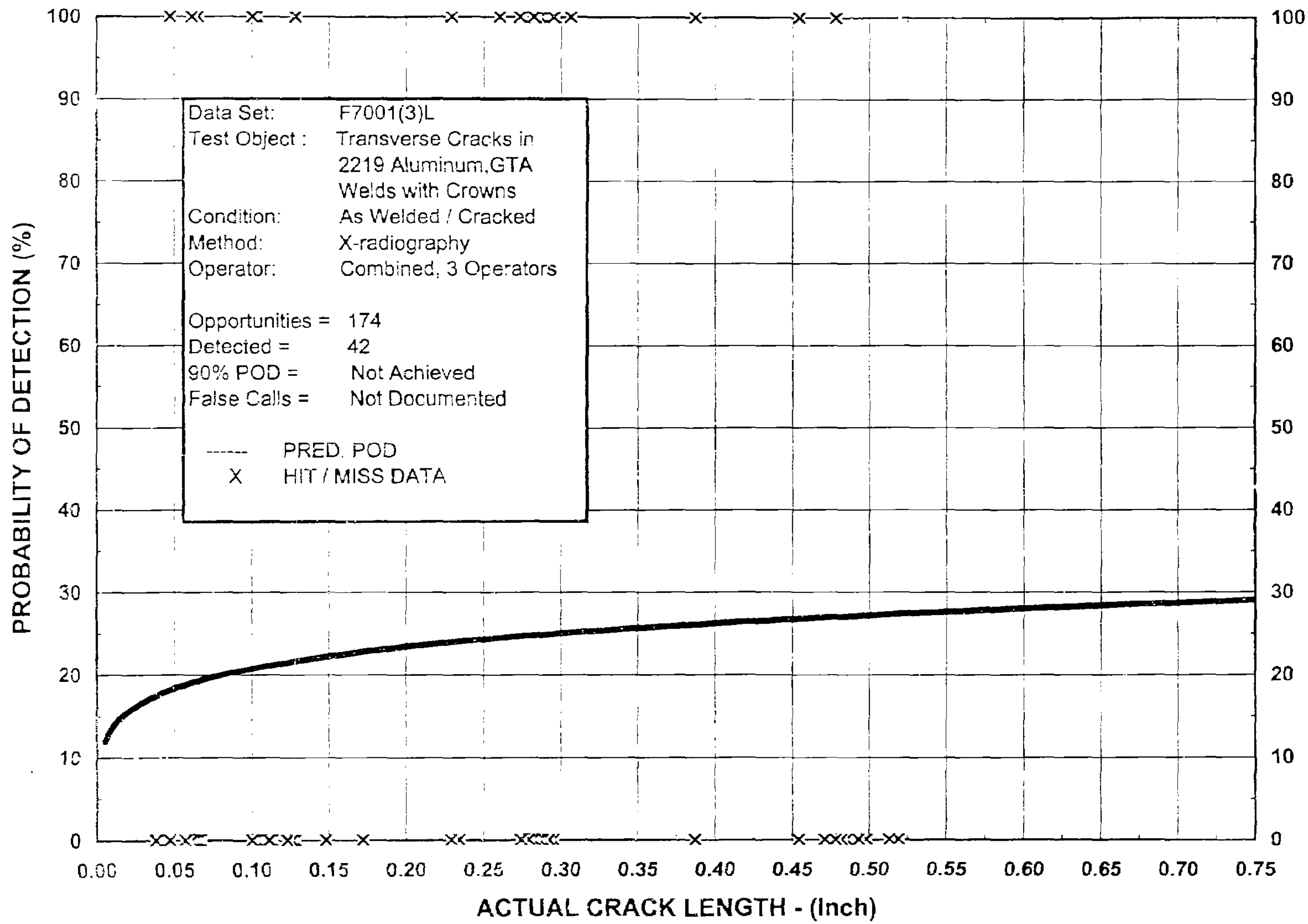
X-Radiography- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched



F6003(3)D
6/97 -F6003(3)D

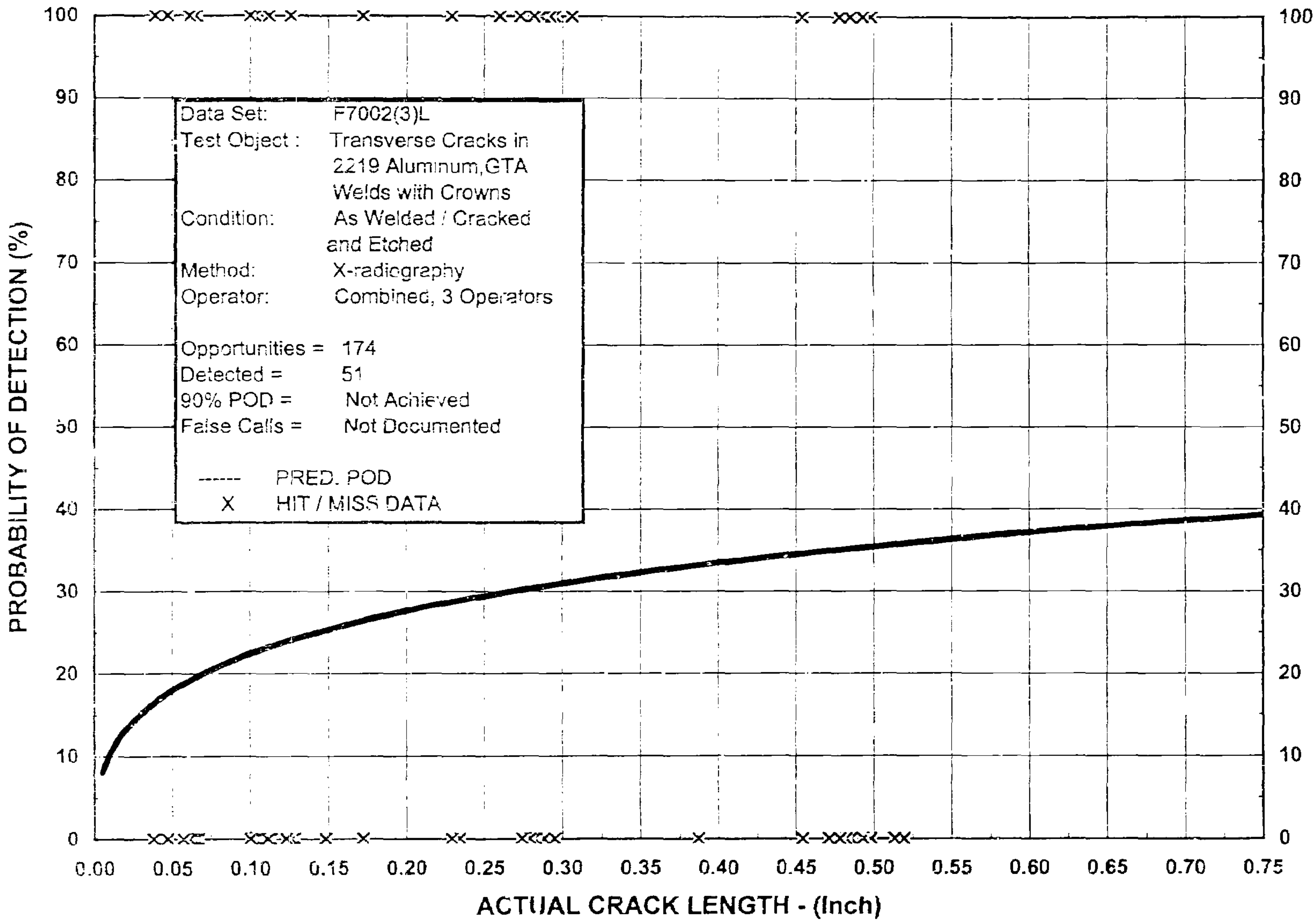
X-Radiography- 3 Operators Longitudinal Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Proof Loaded

F7000(3)L,D	**DATA SET DESCRIPTION - TRANSVERSE CRACKS IN WELDS WITH CROWNS**
METHOD:	X-radiographic Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	45 and 70 KV; 20 ma; 48" FFD;Time: 1 1/2 to 2 1/2 min.(Thickness); Kodak Type M, Automatic Processing
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and Scarfed"; -02, "After Etch"; and -03, "After Proof Loading".
SURFACE FINISH:	*Approximately 125 RMS - commercial plate material surface and weld bead surfaces*
APPLICATION:	Exposure time adjusted with thickness to produce a 3.0 film density and a 2T penetrameter image
DATA SET IDENTIFIER:	F7001(3)L/D; F7002(3)L/D; F7003(3)L/D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	174 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)D/L = 70; -02(3)D/L = 51; -03(3)D/L= 42
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in *a continuous function probability of detection* (POD).
	166 surface open flaws were induced in 63 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED"; "AFTER ETCH"; "AFTER PROOF";
	-01 L, A = Not Achieved -02 L, A= Not Achieved -03 L, A= Not Achieved
	-01 D, A= Not Achieved -02 D, A= Not Achieved -03 D, A= Not Achieved
Test Specimen Descriptions	**Authors Note:** The test set was not optimized for the X-radiographic inspection method, but provides a good assessment of the effects of etching and proof loading on a tight fatigue crack defect.
in AB000(3)L, Page 2	



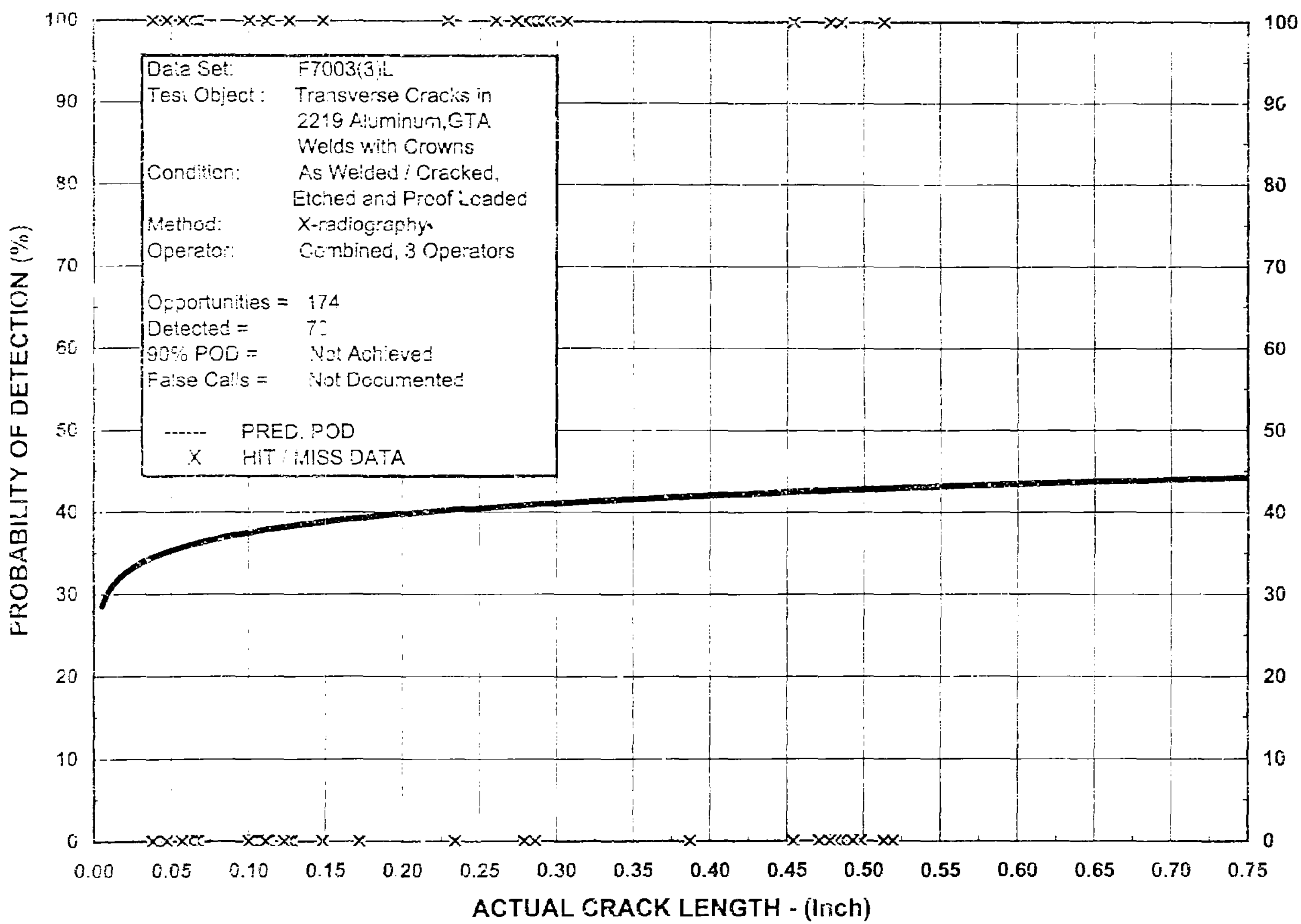
F7001(3)L
6/97 -F7001(3)L

X-Radiographic Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



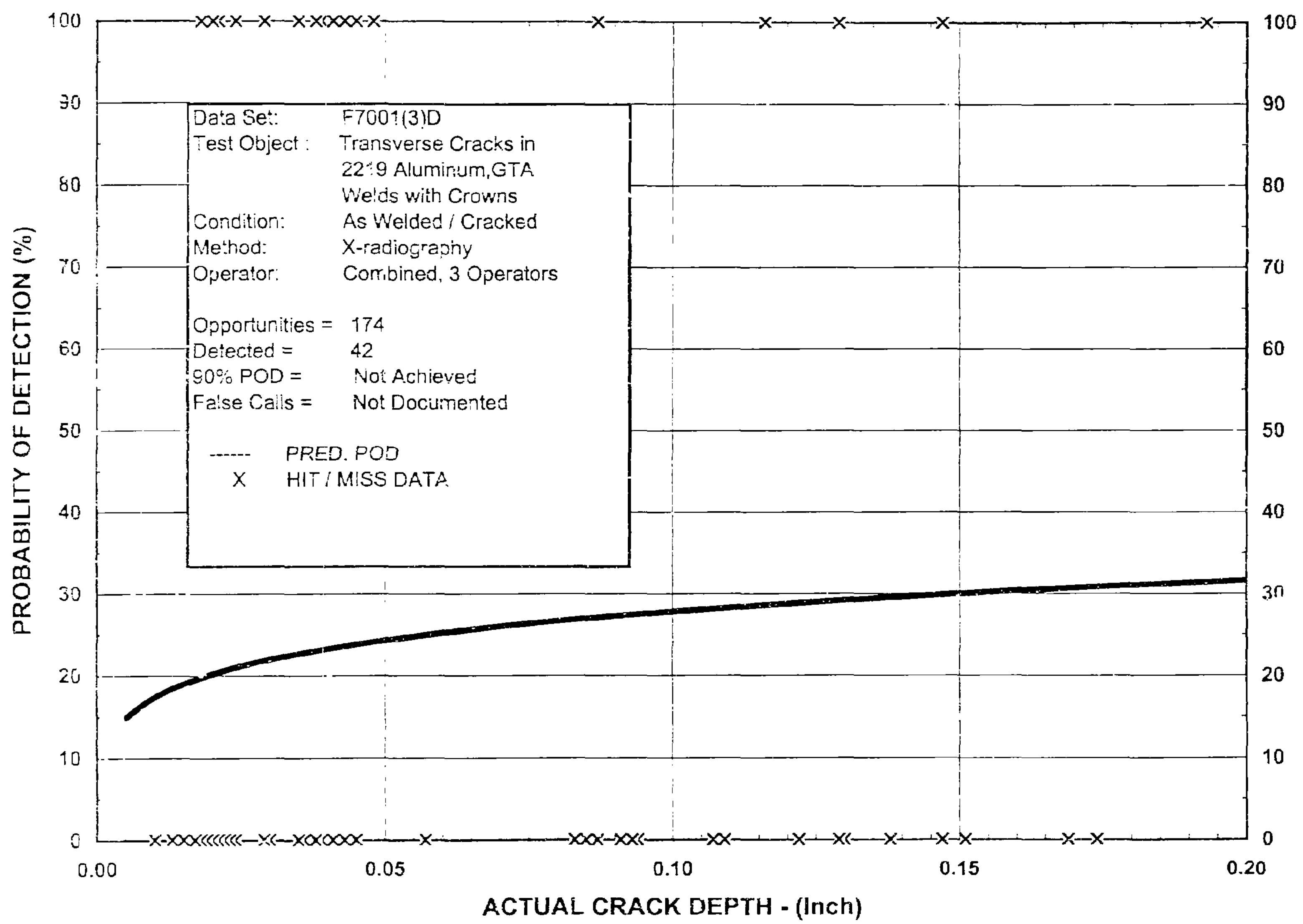
F7002(3)L
6/97 -F7002(3)L

X-Radiographic Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched



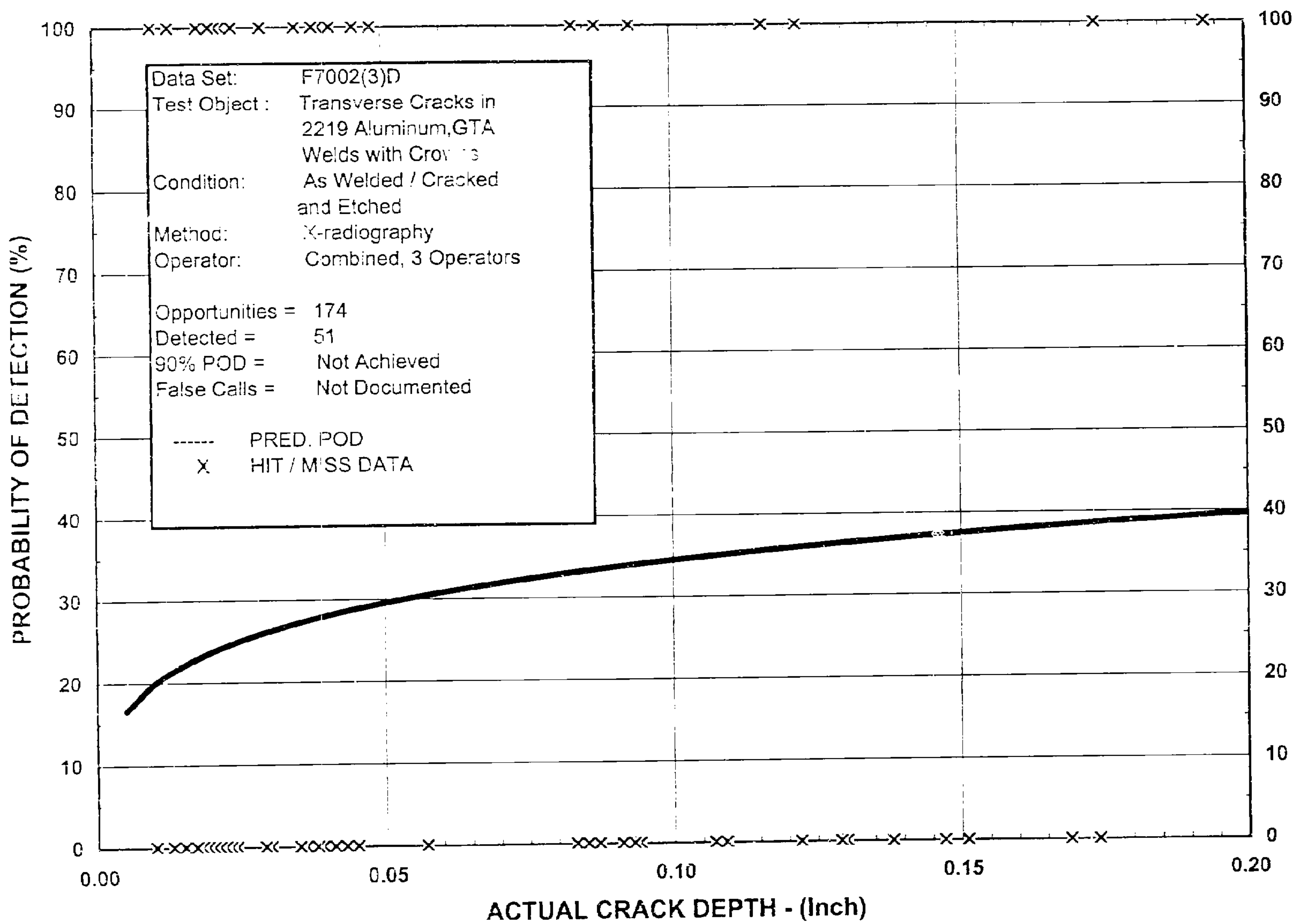
F7003(3)L
6/97 -F7003(3)L

X-Radiographic Inspection- 3 Operators Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed, Etched and Proof Loaded



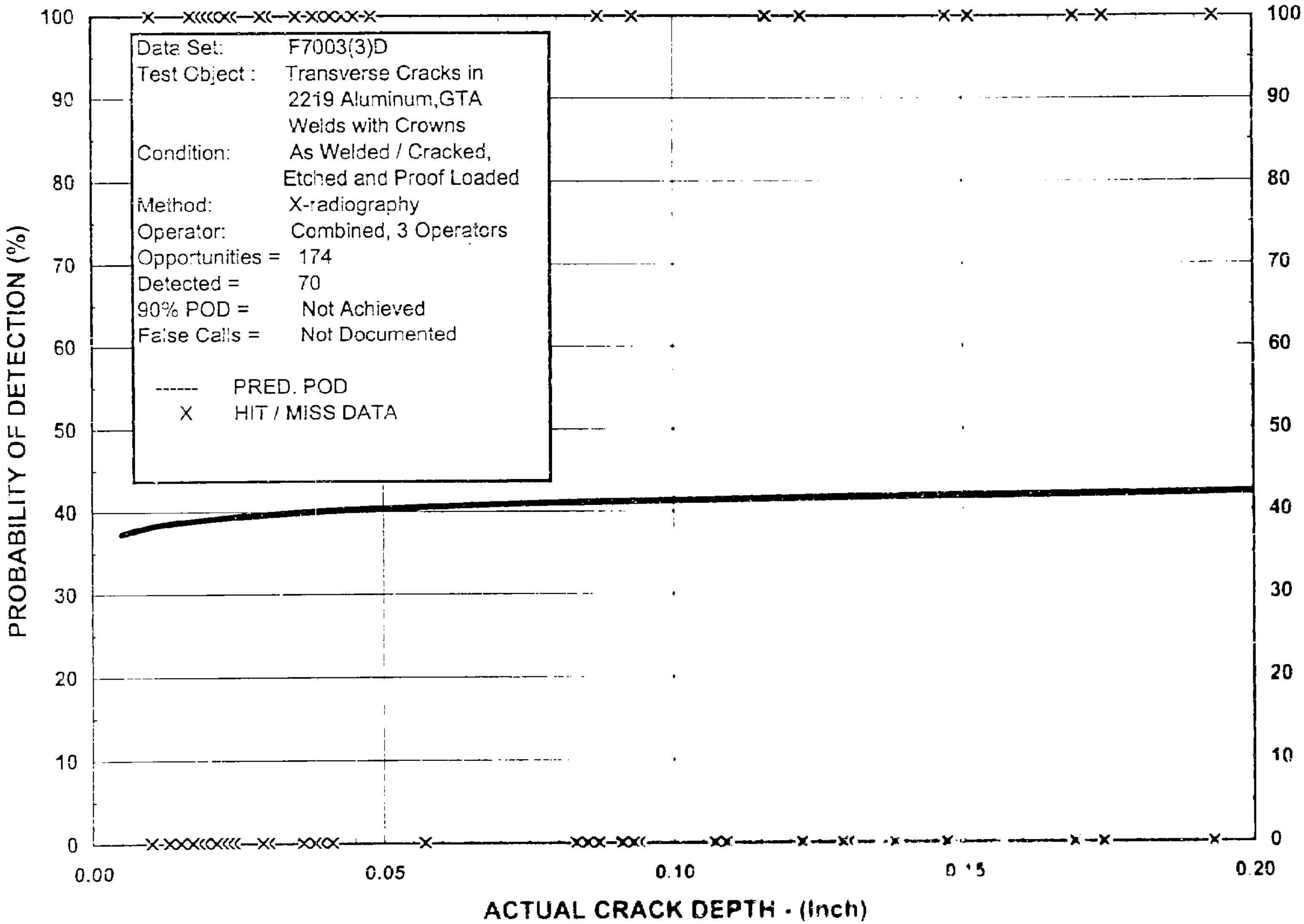
F7001(3)D
6/97 -F7001(3)D

X-Radiographic Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked and Scarfed



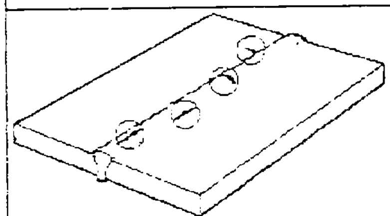
F7002(3)D
6/97 -F7002(3)D

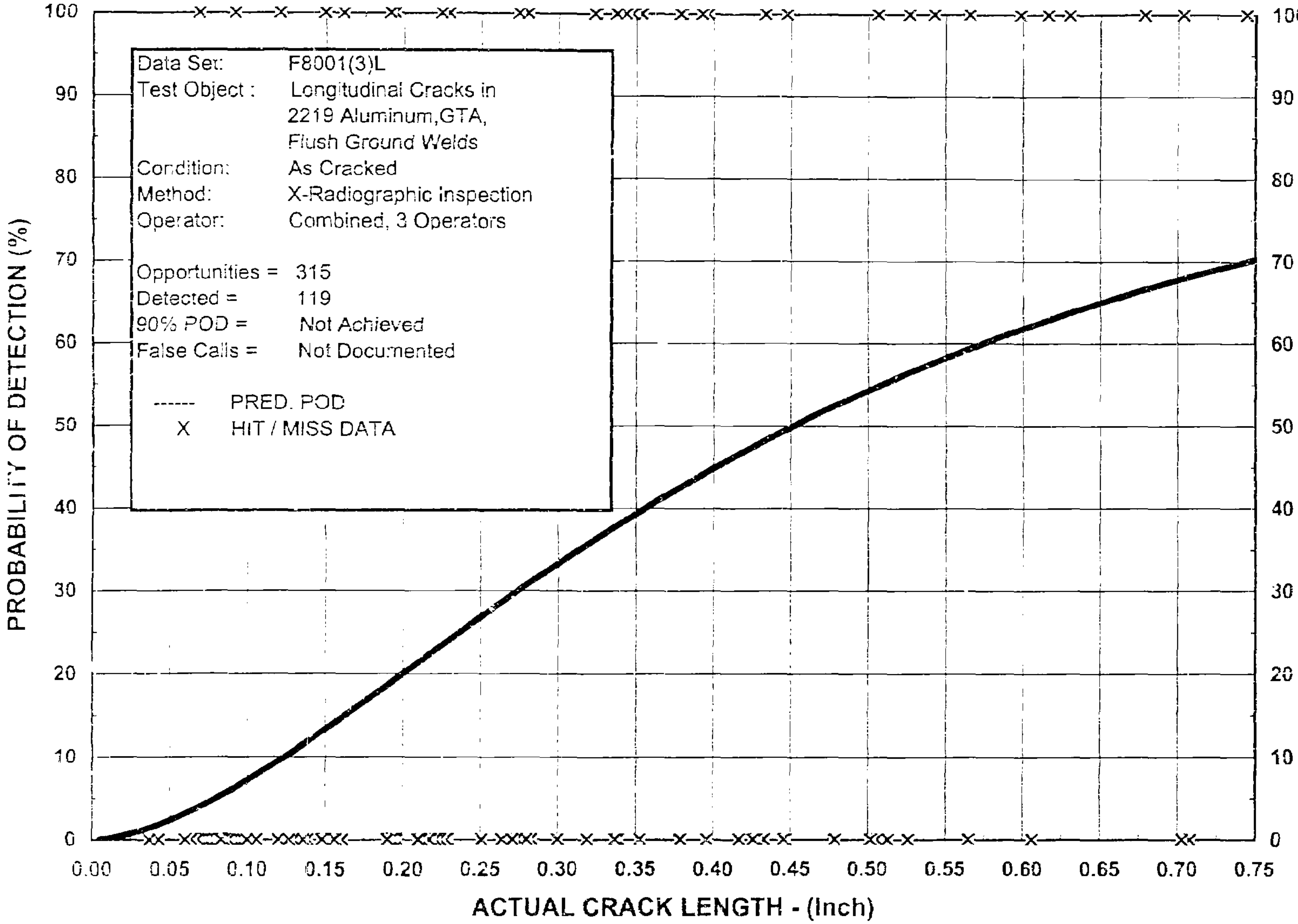
X-Radiographic Inspection- 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA Welds As Cracked, Scarfed and Etched



F7003(3)D
6/97 -F7003(3)D

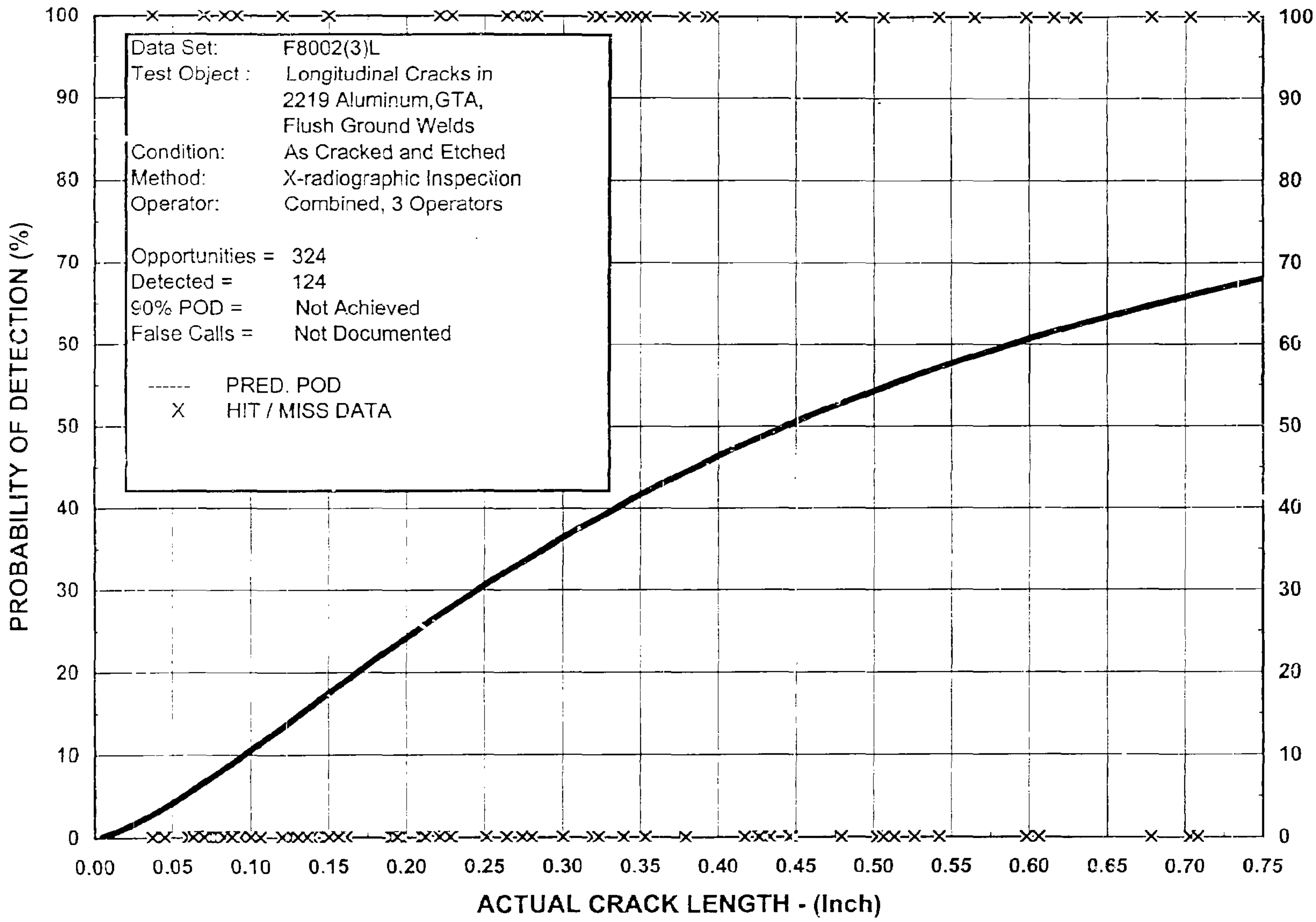
X-Radiographic Inspection- 3 Operators Transverse Fatigue Cracks In 2219 Aluminum GTA Welds
As Cracked, Scarfed, Etched and Proof Loaded

F8000(3)L,D	**DATA SET DESCRIPTION - LONGITUDINAL CRACKS IN FLUSH WELDS**
METHOD:	X-radiographic Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	45 and 70 KV; 20 ma; 48" FFD;Time: 1 1/2 to 2 1/2 min.(Thickness); Kodak Type M, Automatic Processing
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and Scarfed"; -02, "After Etch"; and -03, "After Proof Loading".
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Exposure time adjusted with thickness to produce a 3.0 film density and a 2T penetrameter image
DATA SET IDENTIFIER:	F8001(3)L/D; F8002(3)L/D; F8003(3)L/D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	324 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)D/L = 119; -02(3)D/L =124; -03(3)D/L= 185 (3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **<u>The Detection of Tightly Closed Flaws by Nondestructive Testing Methods</u>**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	166 surface open flaws were induced in 63 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED"; "AFTER ETCH"; "AFTER PROOF";
	-01 L, A = Not Achieved -02 L, A= Not Achieved -03 L, A= Not Achieved
	-01 D, A= Not Achieved -02 D, A= Not Achieved -03 D, A= Not Achieved
Test Specimen Descriptions	**Authors Note:** The test set was not optimized for the X-radiographic inspection method, but provides a good assessment of the effects of etching and proof loading on a tight fatigue crack defect.
in AB000(3)L. Page 2	



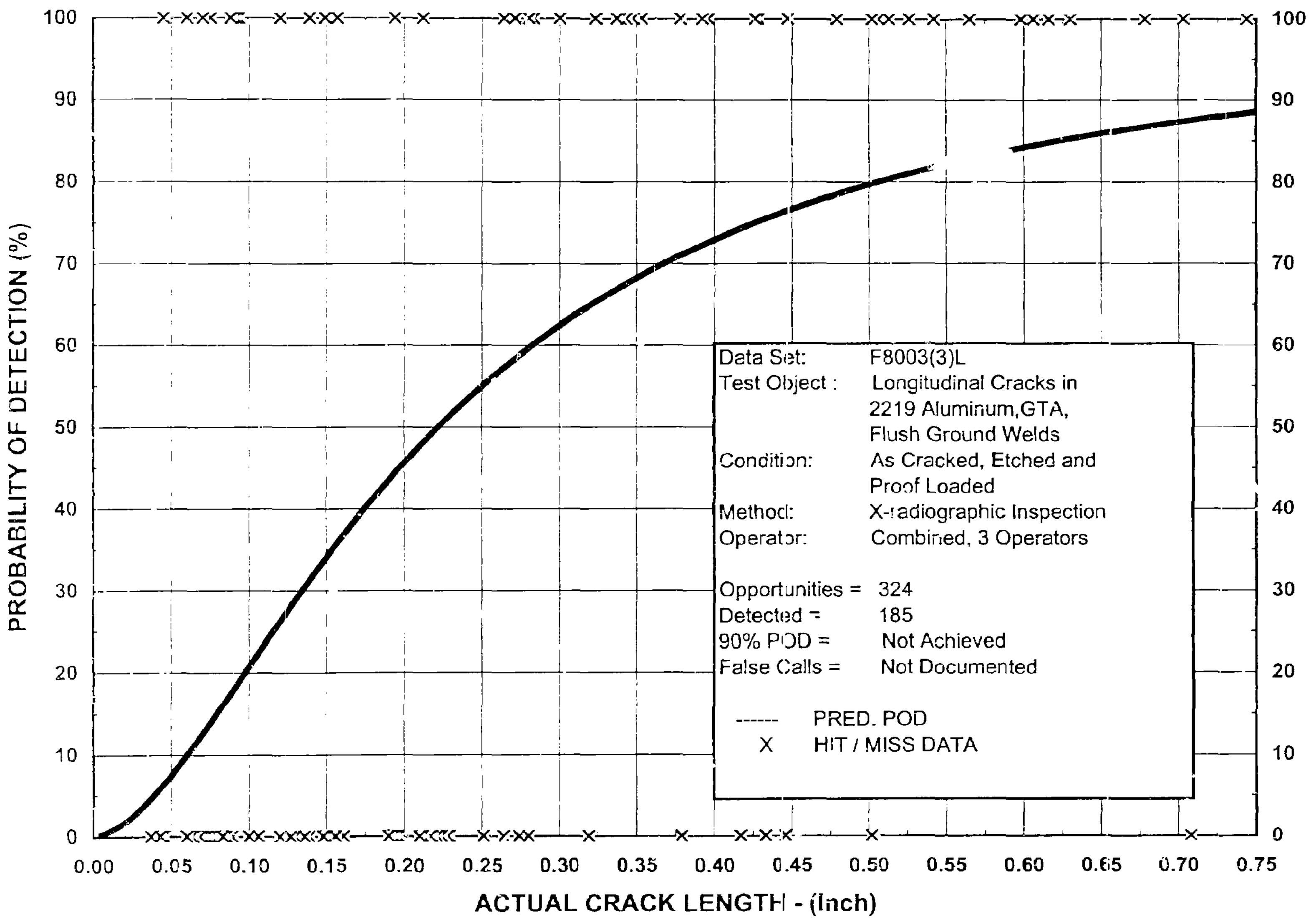
F8001(3)L
6'97 -F8001(3)L

X-Radiographic Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



F8002(3)L
6/97 - F8002(3)L

X-radiographic Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching

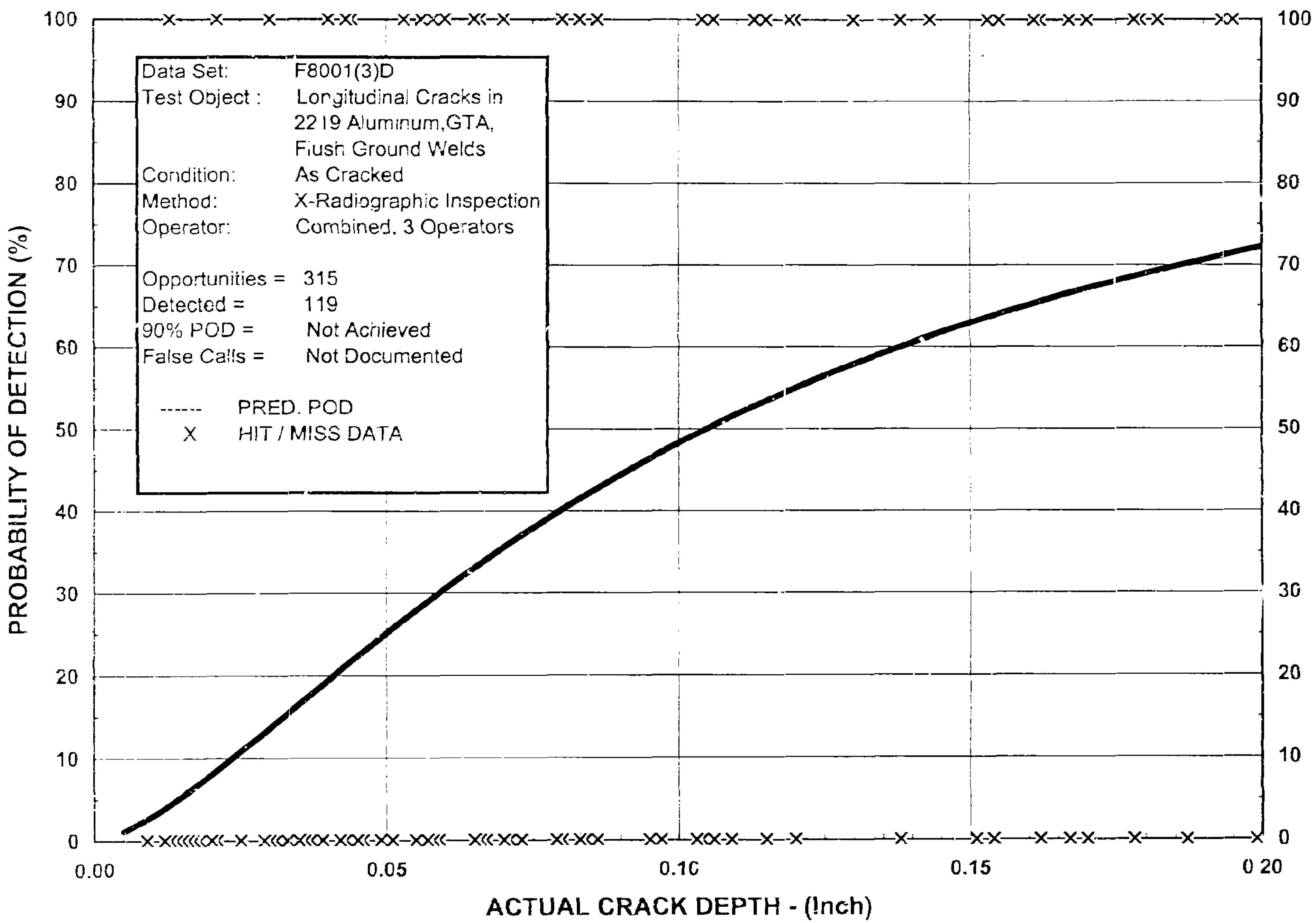


F8003(3)L

6/97 - F8003(3)L

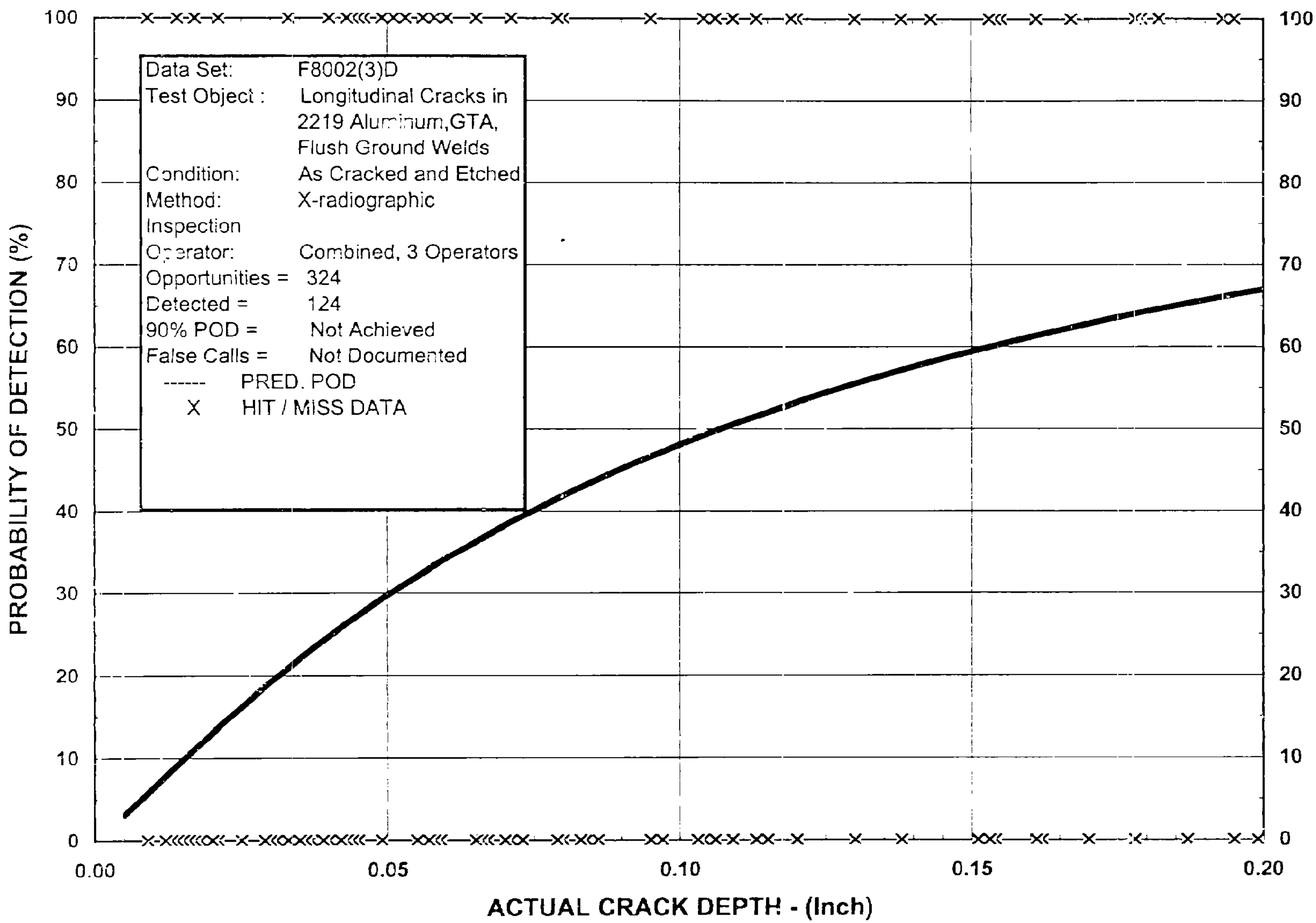
X-radiographic Inspection- 3 Operators

Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading



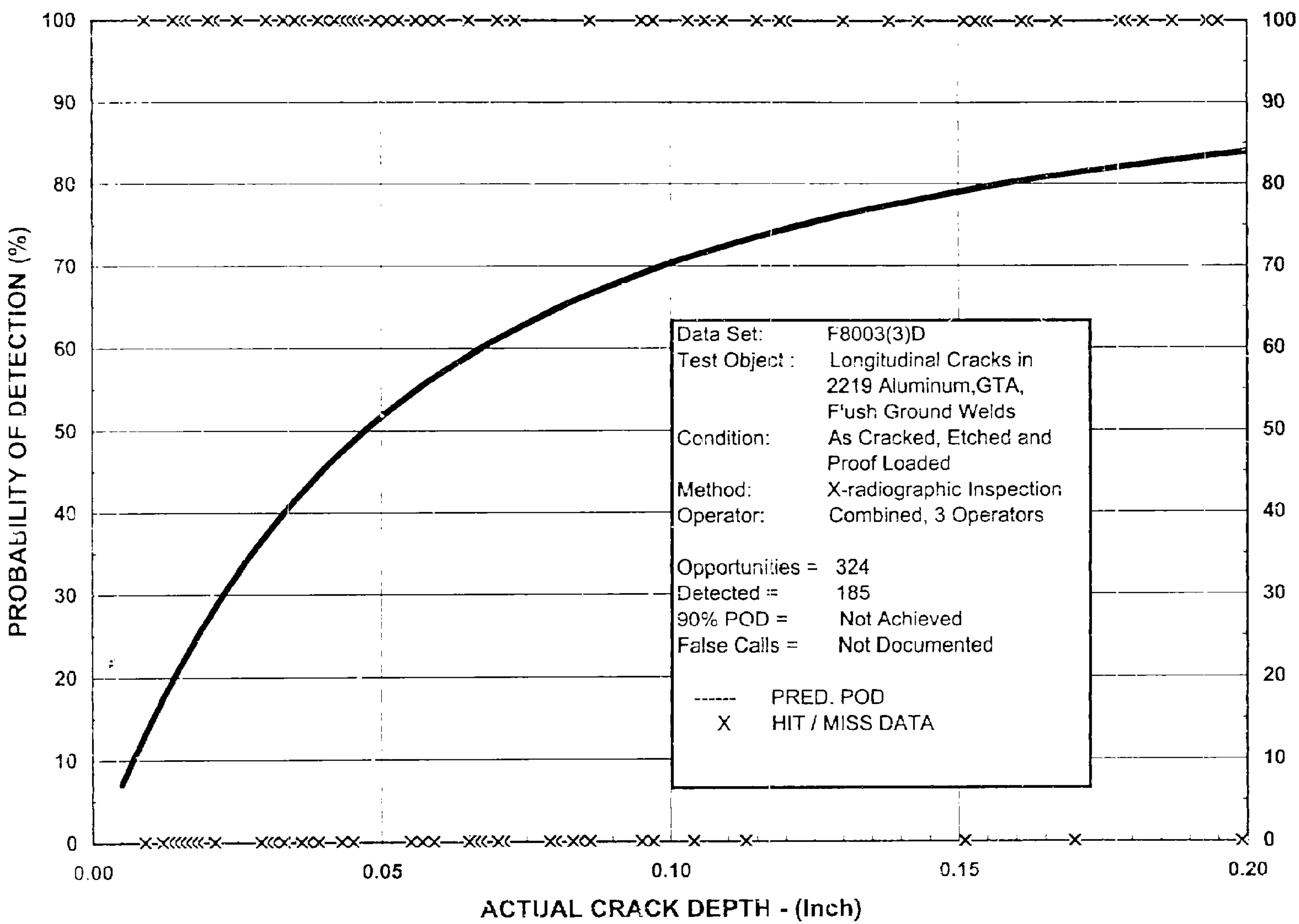
F8001(3)D
6/97 -F8001(3)D

X-Radiographic Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



F8002(3)D
6/97 - F8002(3)D

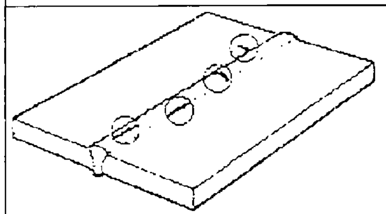
X-radiographic Inspection- 3 Operators
Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching

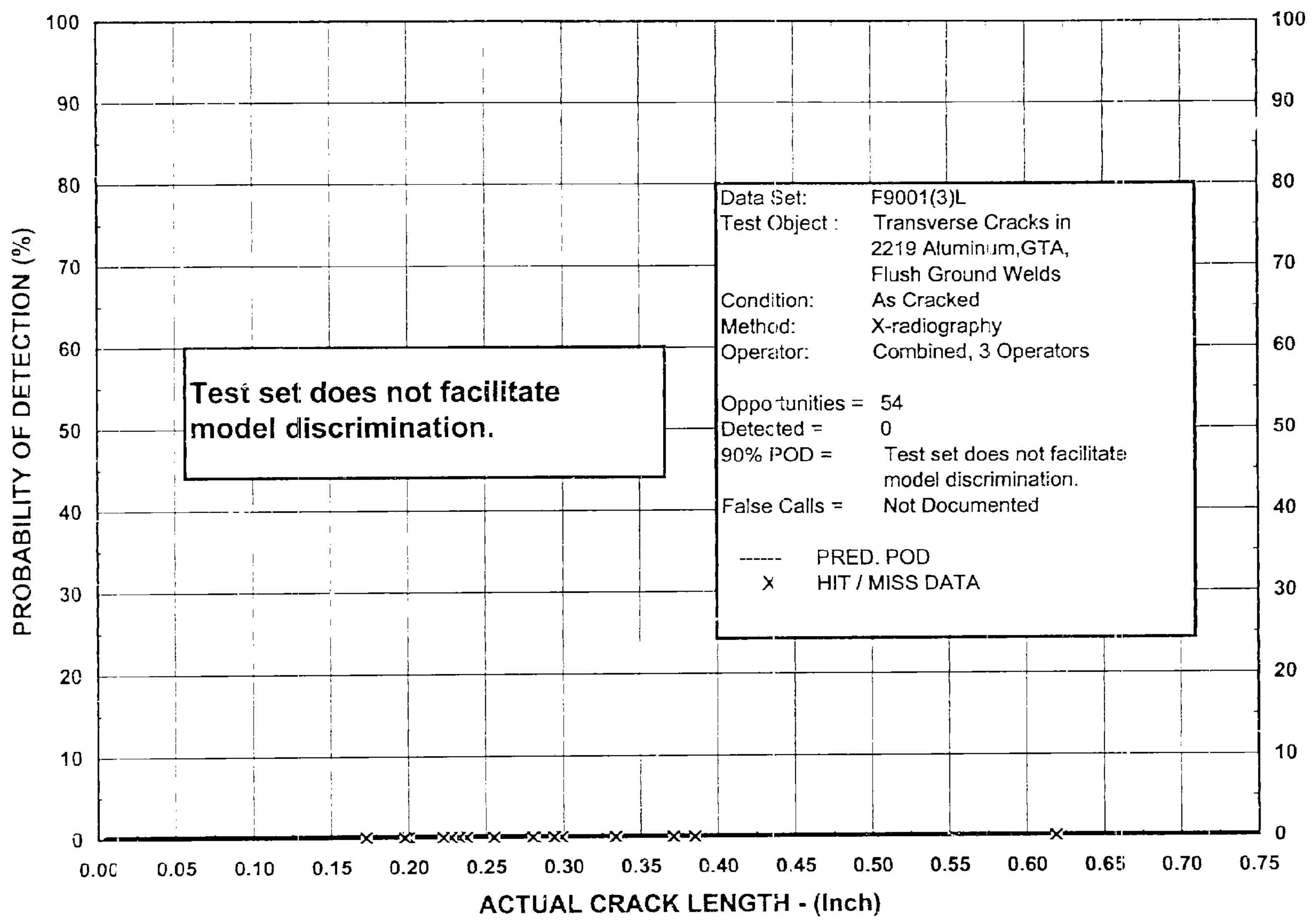


F8003(3)D

X-radiographic Inspection- 3 Operators

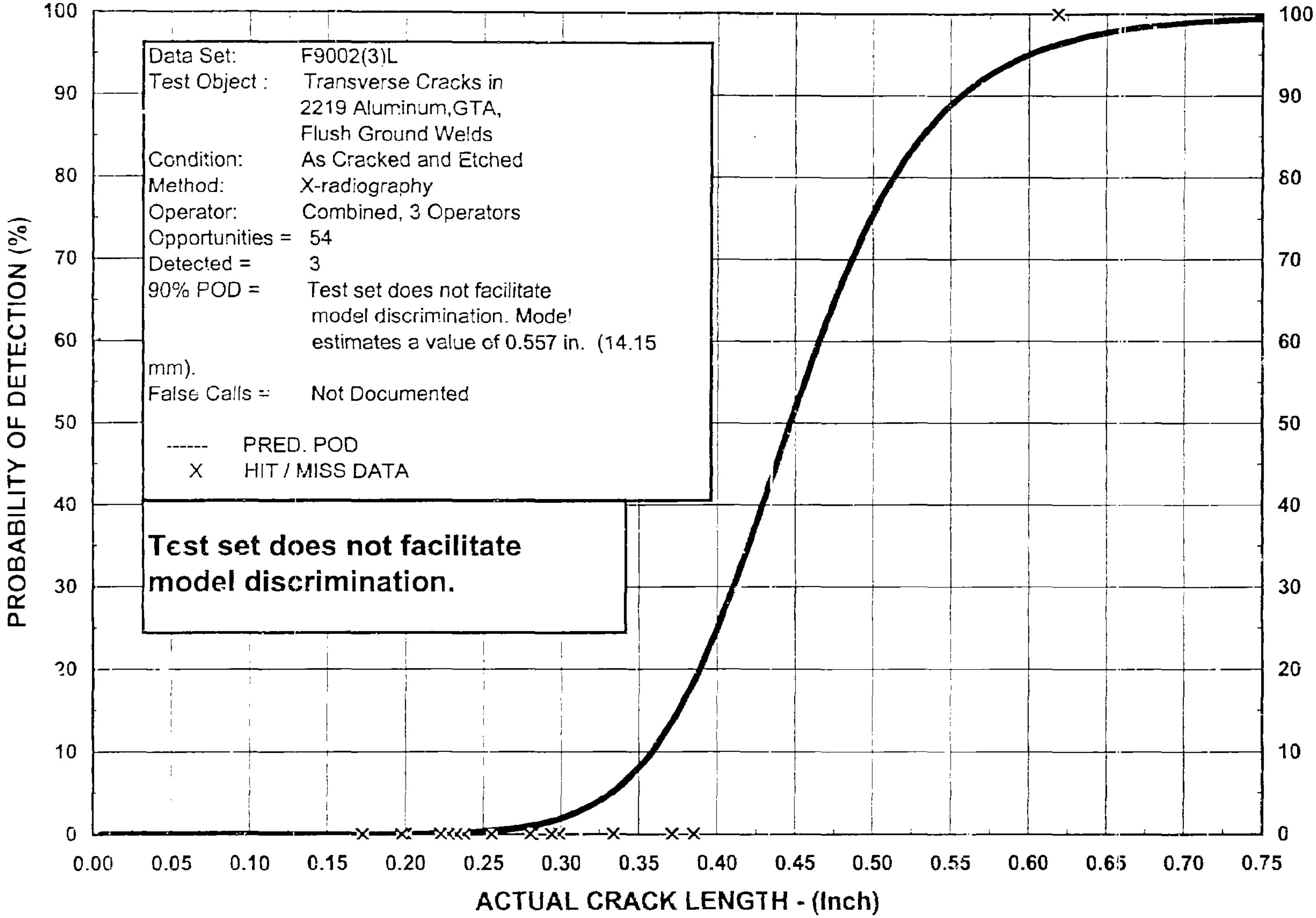
6/97 - F8003(3)D Longitudinal Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading

F9000(3)L,D	**DATA SET DESCRIPTION - TRANSVERSERSE CRACKS IN FLUSH WELDS**
METHOD:	X-radiographic Inspection
TEST OBJECT TYPE:	Gas Tungsten Arc (GTA), automatic welds in 2219 aluminum alloy. Fusion and filler pass from one side.
NDE PROCEDURE:	45 and 70 KV; 20 ma; 48" FFD;Time: 1 1/2 to 2 1/2 min.(Thickness); Kodak Type M, Automatic Processing
ARTIFACT TYPE:	Fatigue Cracks / Root radius - R< 0. 70 (Shaped EDM notch initiation, in bending and tension / tension)
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/2c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87; 2319 weld filler wire
TEST OBJECT THICKNESS:	Base Plate - 0.125 inch and 0.500 inch nominal. Approximate weld reinforcement of 1/8 T
TEST OBJECT CONDITION:	-01,"As welded and Scarfed"; -02, "After Etch"; and -03, "After Proof Loading".
SURFACE FINISH:	Approximately 125 RMS - commercial plate material surface and weld bead surfaces
APPLICATION:	Exposure time adjusted with thickness to produce a 3.0 film density and a 2T penetrameter image
DATA SET IDENTIFIER:	F8001(3)L/D; F8002(3)L/D; F8003(3)L/D
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	54 Cracks / opportunities. (Some cracks were lost during proof loading)
DETECTED:	-01(3)D/L = 0; -02(3)D/L = 3 -03(3)D/L= 3 (3 operators)
FALSE CALLS:	Not reported
REFERENCE:	NASA 9-13578, Rummel, Ward D., Richard A. Rathke, Paul H. Todd Jr., and Steve J. Mullen **The Detection of Tightly Closed Flaws by Nondestructive Testing Methods**, October 1975.
DATE:	June 1973 - October 1975
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	166 surface open flaws were induced in 63 panels. Approximately 90% of the weld lengths were unflawed.
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	The program provided an assessment of the effects of part geometry on inspection capabilities.
	90% POD - "AS PRODUCED"; "AFTER ETCH"; "AFTER PROOF";
	-01 L, A = No Test -02 L, A= No Test -03 L, A= No Test
	-01 D, A= No Test -02 D, A= No Test -03 D, A= No Test
Test Specimen Descriptions	**Authors Note:** This test set was too small to provide discrimination by the analysis model
in AB000(3)L, Page 2	



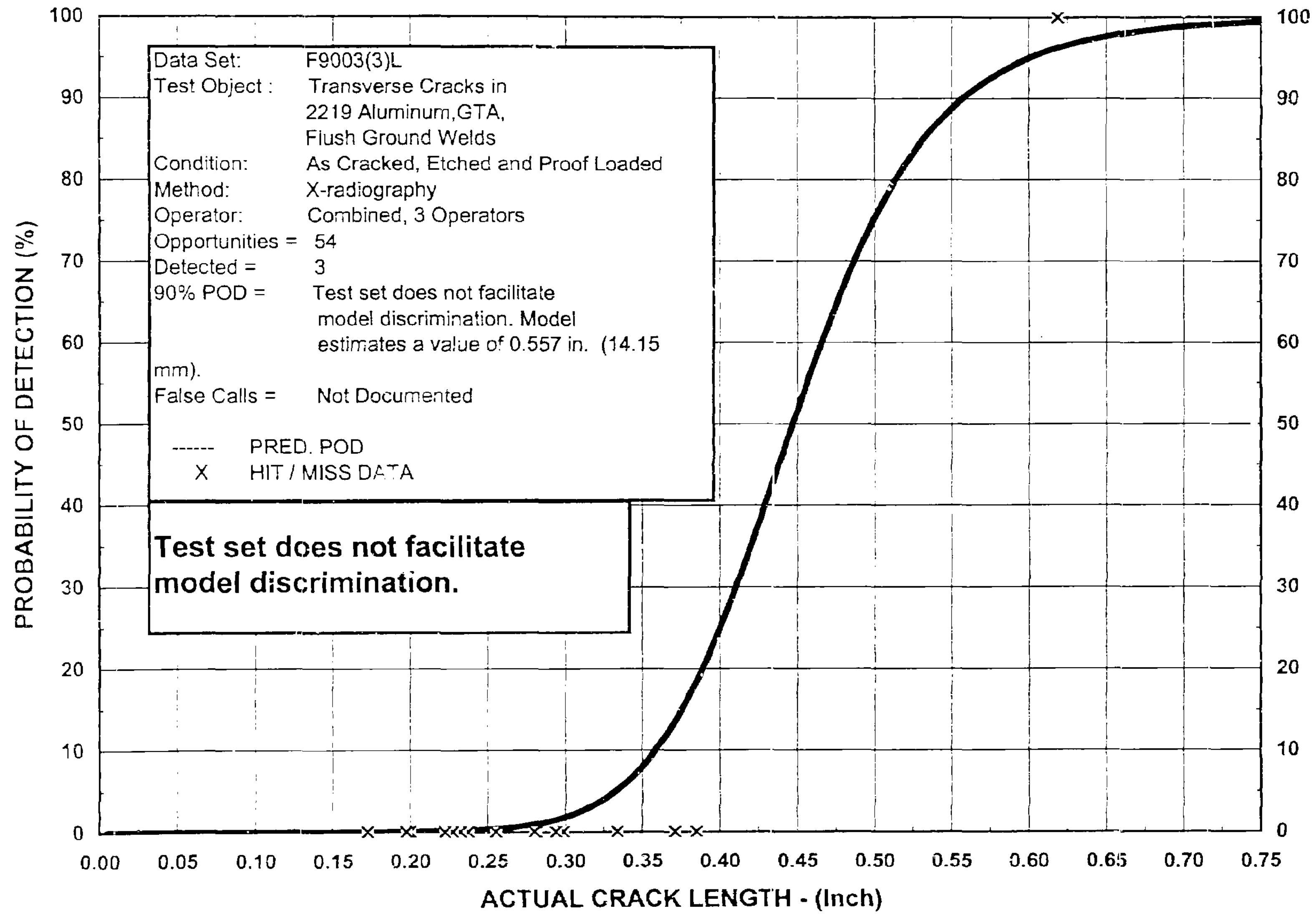
X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing

F9001(3)L
8/97 - F9001(3)L



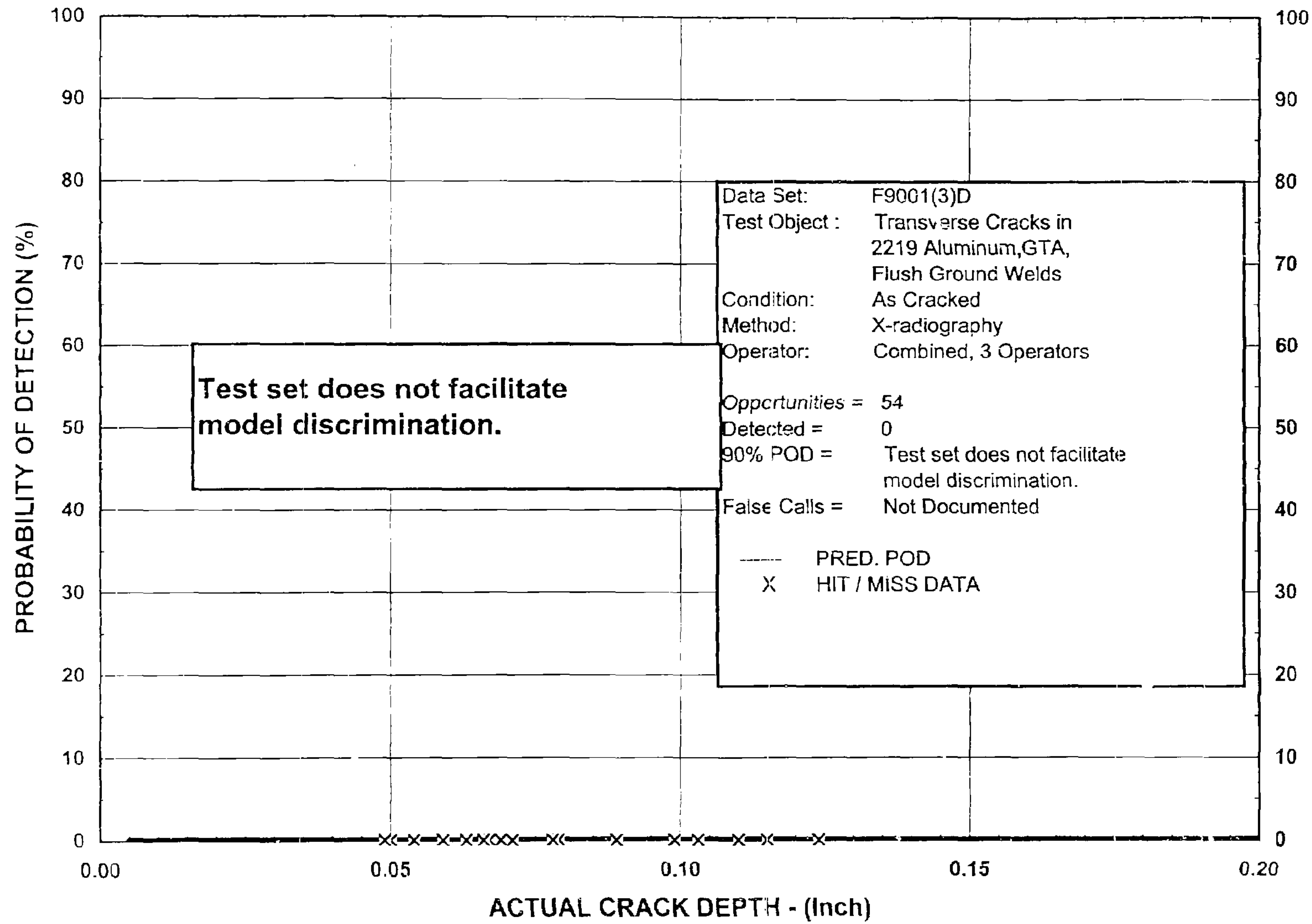
F9002(3)L
8/97 - F9002(3)L

X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching



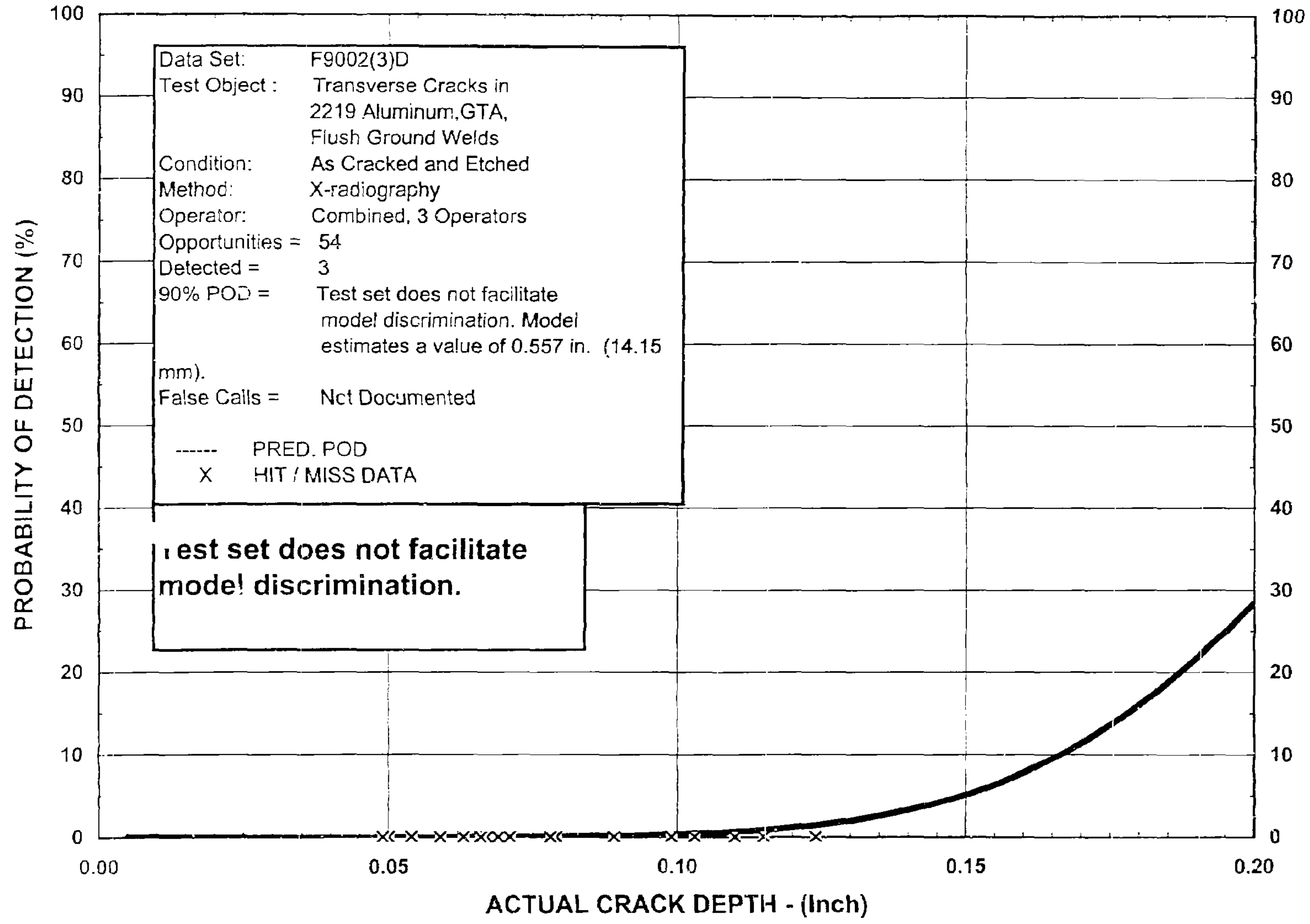
F9003(3)L
8/97 - F9003(3)L

X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading



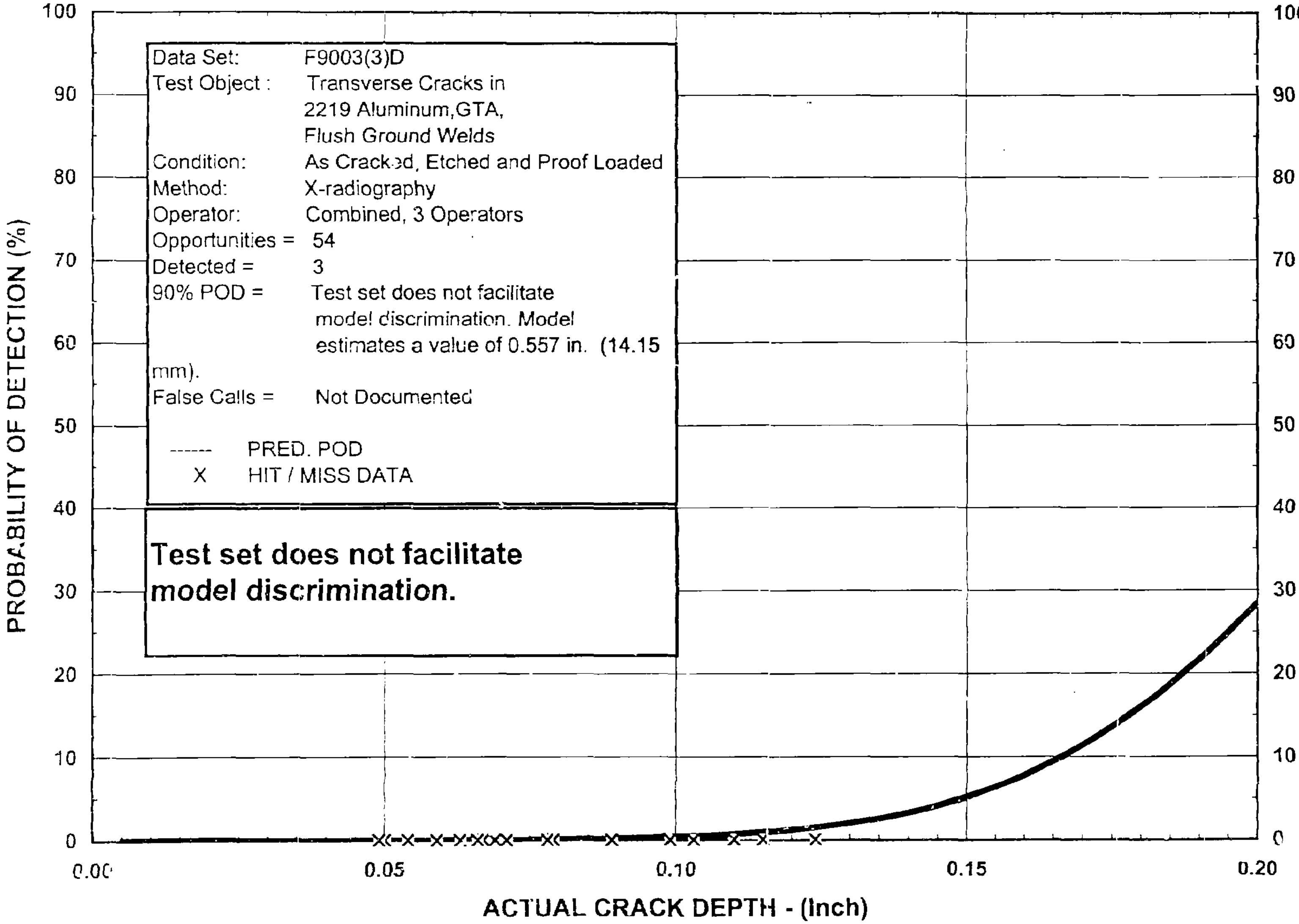
F9001(3)D
8/97 - F9001(3)D

X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing



F9002(3)D
8/97 - F9002(3)D

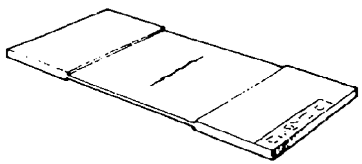
X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing and Etching



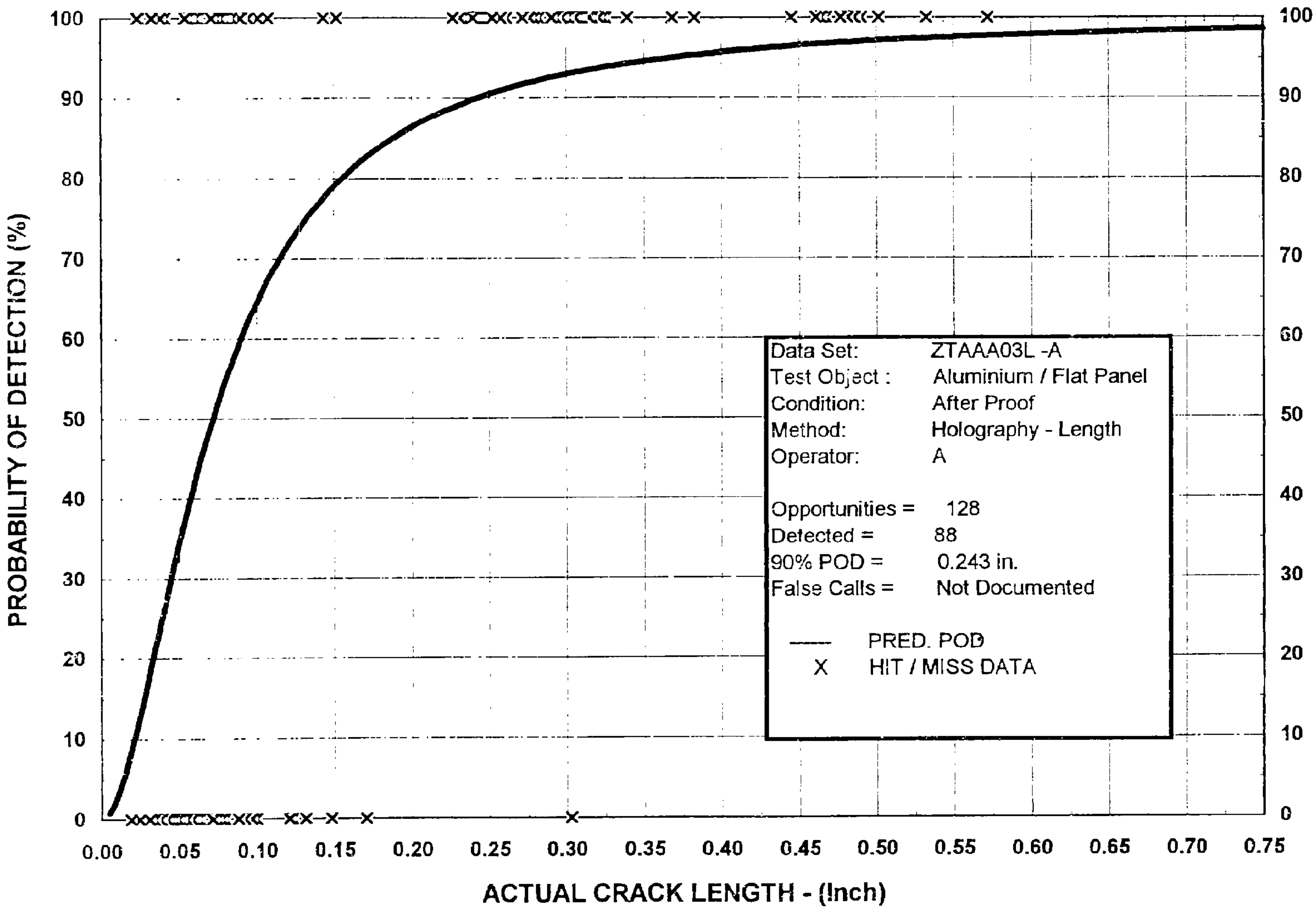
F9003(3)D
8/97 - F9003(3)D

X-radiographic Inspection - 3 Operators
Transverse Fatigue Cracks in 2219 Aluminum GTA, Flush Welds After Scarfing, Etching and Proof Loading

ZT - 01 (1)	DATA SET DESCRIPTION
METHOD:	Holographic Interferometry
TEST OBJECT TYPE:	Flat Plate - 3.5 inches by 16 inches, cracks on both sides
NDE PROCEDURE:	Holography - film / TENSION LOAD - 0.060" Panels = 5100 psi; 0.225" Panels - 5950 psi
ARTIFACT TYPE:	Fatigue Cracks - R< 0. 70 (Shaped EDM starter notch initiation, growth in bending and tension / tension
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO 0.5 (a/2c) — DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	2219 Aluminum T-87
TEST OBJECT THICKNESS:	0.060 and 0.225 inch nominal
TEST OBJECT CONDITION:	-03, "After Proof"
SURFACE FINISH:	125 and 32 RMS - representative of good machining practices
APPLICATION:	Real Time - Live Fringe / Visual read-out
DATA SET IDENTIFIER:	ZTAAA03L-A,B; ZTAAA03D-A,B; ZTAAA03a/T-A,B
TYPE OF DATA:	Hit / Miss with estimated crack lengths
TEST OPPORTUNITIES:	128 Cracks
DETECTED:	A= 88, B= 48
FALSE CALLS:	Not reported
REFERENCE:	NASA CR-2369 Rummel, Ward D., Paul H. Todd Jr., Sandor A. Frecska, and Richard A. Rathke, **The Detection of Fatigue Cracks by Nondestructive Testing Methods**, February 1974.
DATE:	November 1971 - June 1973
WORK SPONSOR:	W.L. Castner, NASA Lyndon B. Johnson Space Center
PERFORMING ORGANIZATION:	Martin Marietta Aerospace, Denver, Colorado
NOTES:	This program was performed in support of the National Aeronautics Administration (NASA) Space Shuttle design and is the first known publication of nondestructive evaluation data in a continuous function probability of detection (POD).
	Flaws were induced in 105 panels (both sides). Thirteen blank panels were included for a total of 118 panels
	The original data analysis was in the form of a moving average plot. Data have been reanalyzed and plotted here by the maximum likelihood / log logistic method.
	A parallel program was conducted by the General Dynamics Corp, San Diego, CA.; test panels were exchanged and inspections repeated by both organizations.

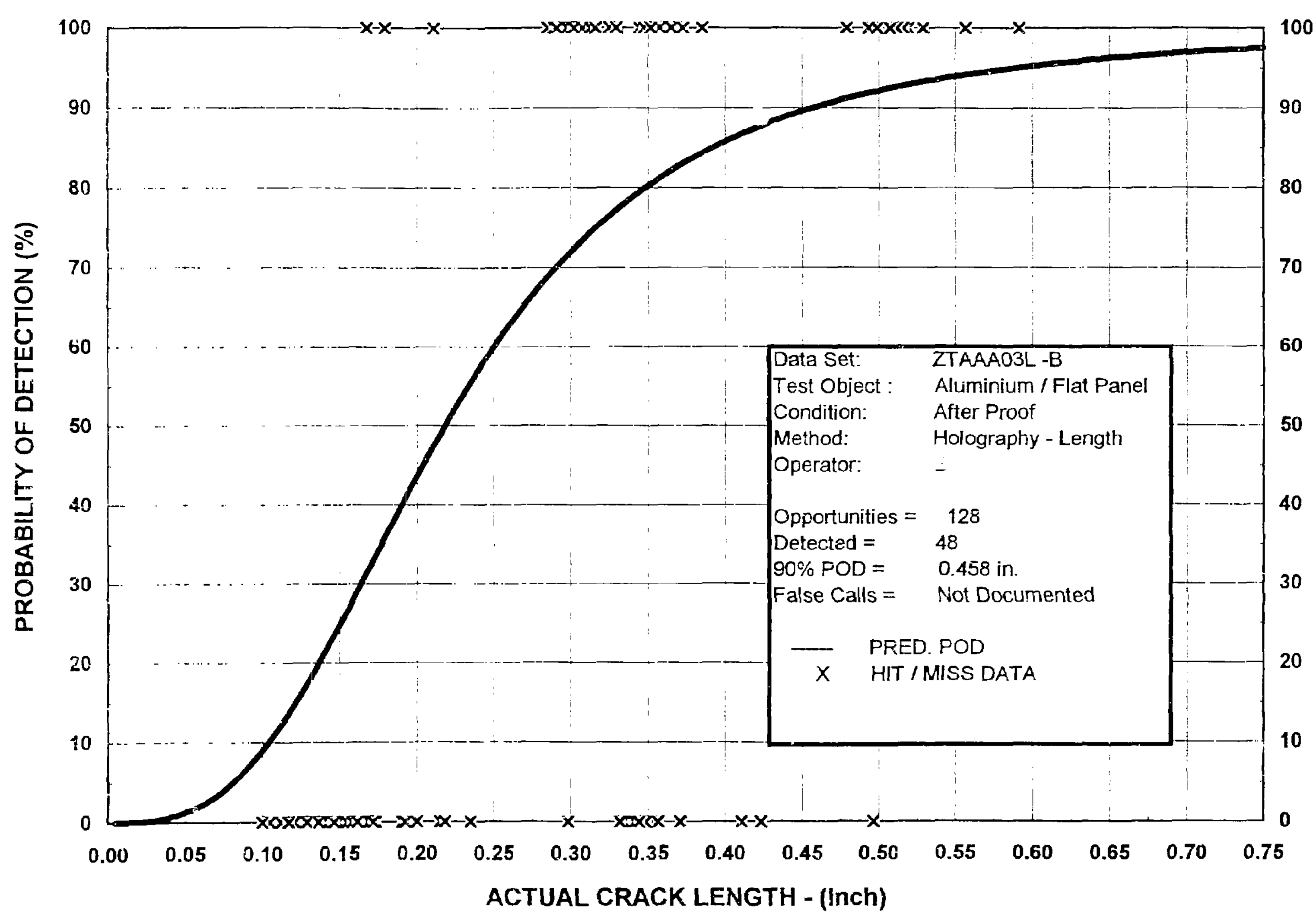


90% POD	LENGTH	DEPTH	a/T
	A= 0.243 in.	A= 0.091 in.	A= 0.636
	B= 0.453 in.	B= 0.103 in.	B= N.A.



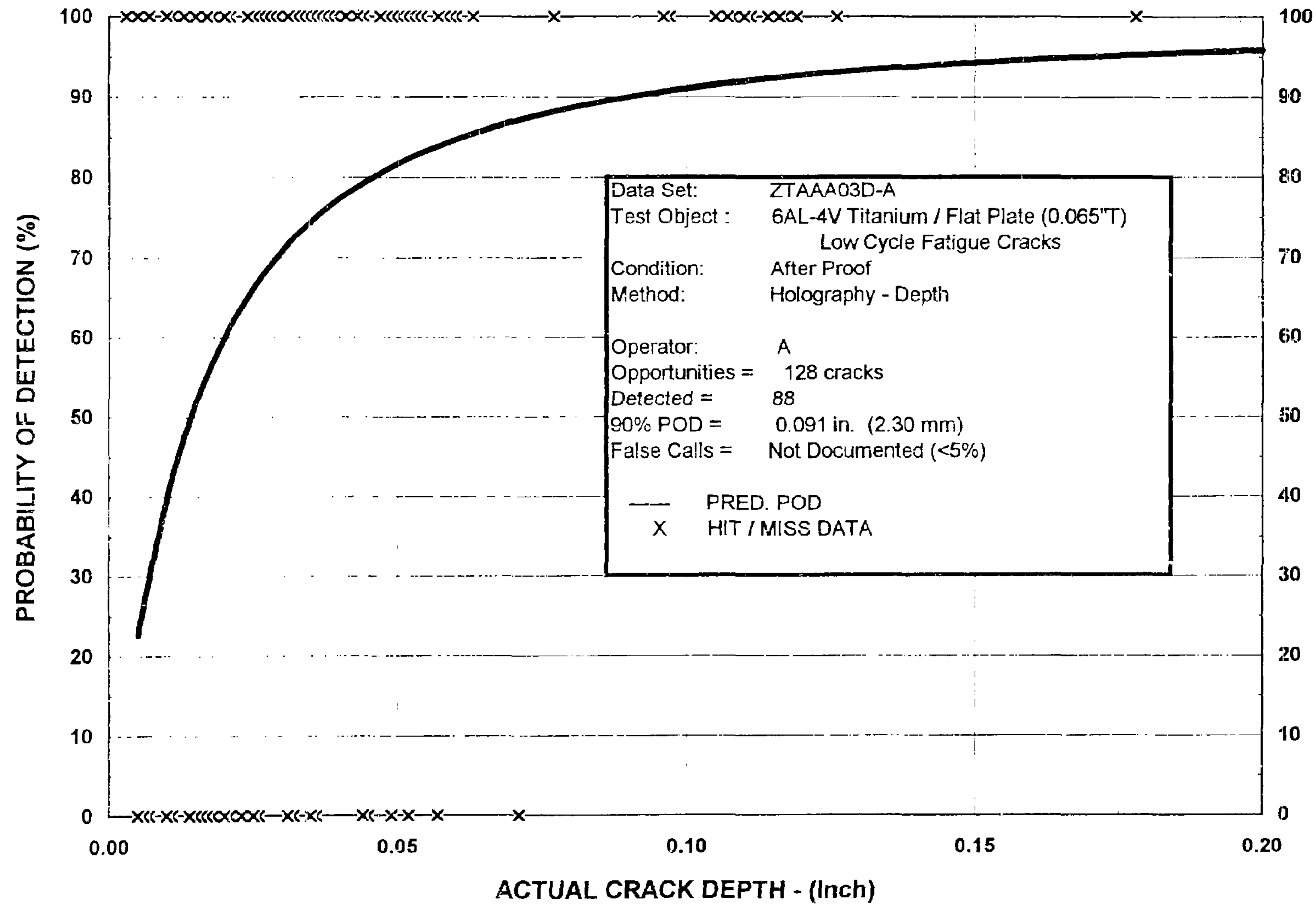
ZT 01 (1) A, HOLOGRAPHIC INTERFEROMETRY
6/95

ZTAAA03L-A
ALUMINUM - FLAT PLATE
OPERATOR A



ZT 01 (1) A, HOLOGRAPHIC INTERFEROMETRY
6/95

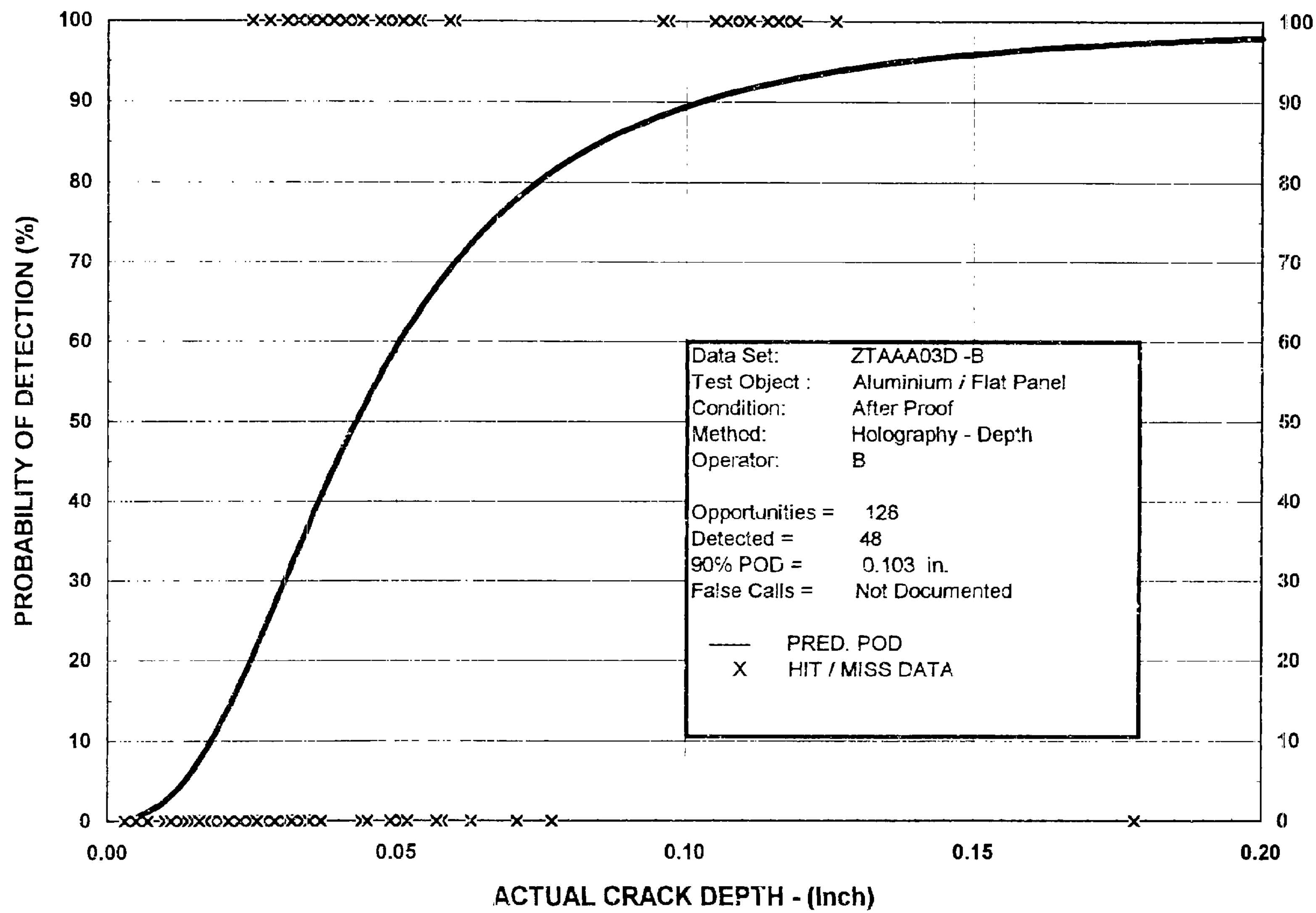
ZTAAA03L-B
ALUMINUM - FLAT PLATE
OPERATOR B



ZT - 01 (1) B, HOLOGRAPHIC INTERFEROMETRY

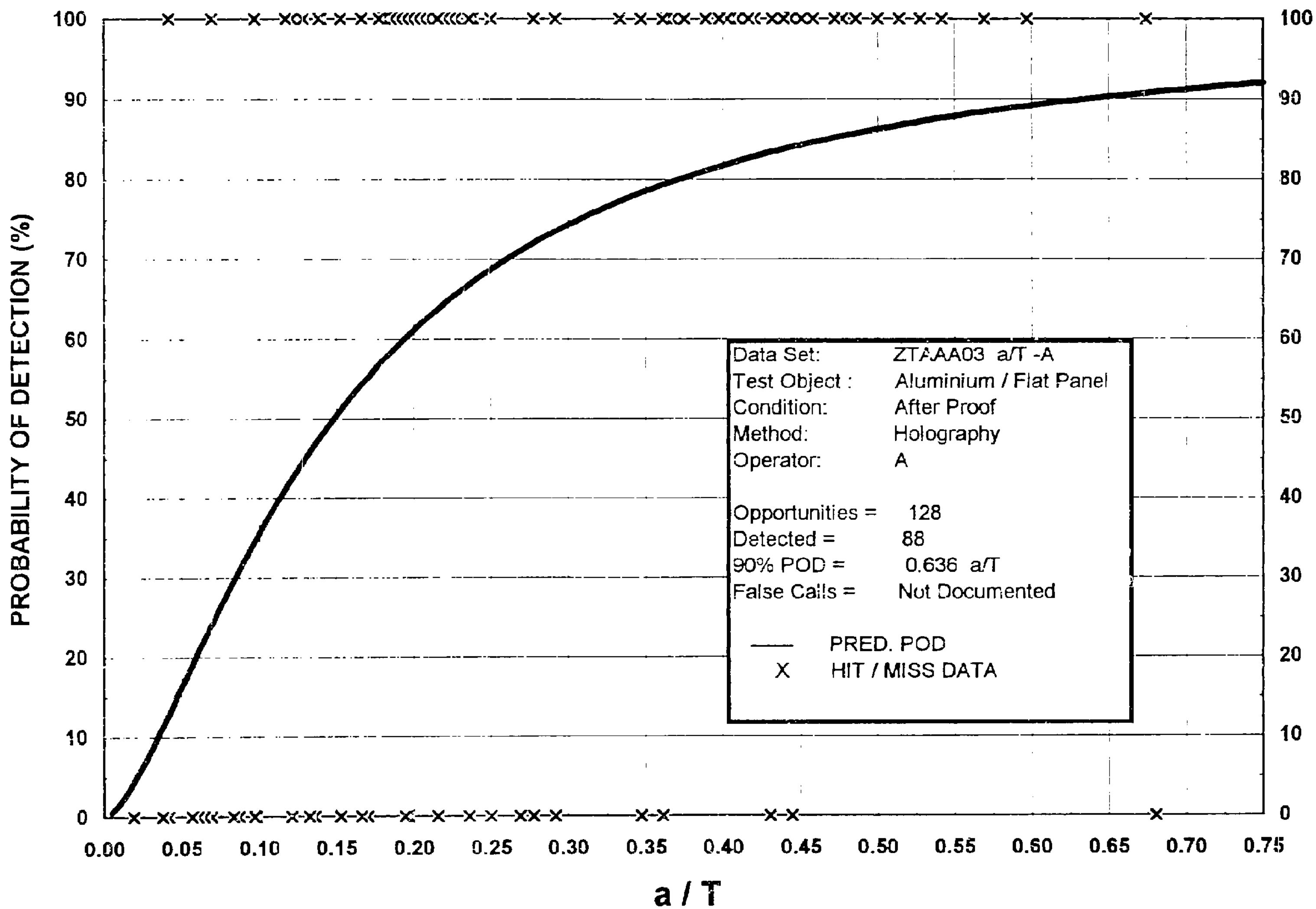
6/95

ZTAAA03D-A
ALUMINUM - FLAT PLATE
OPERATOR A



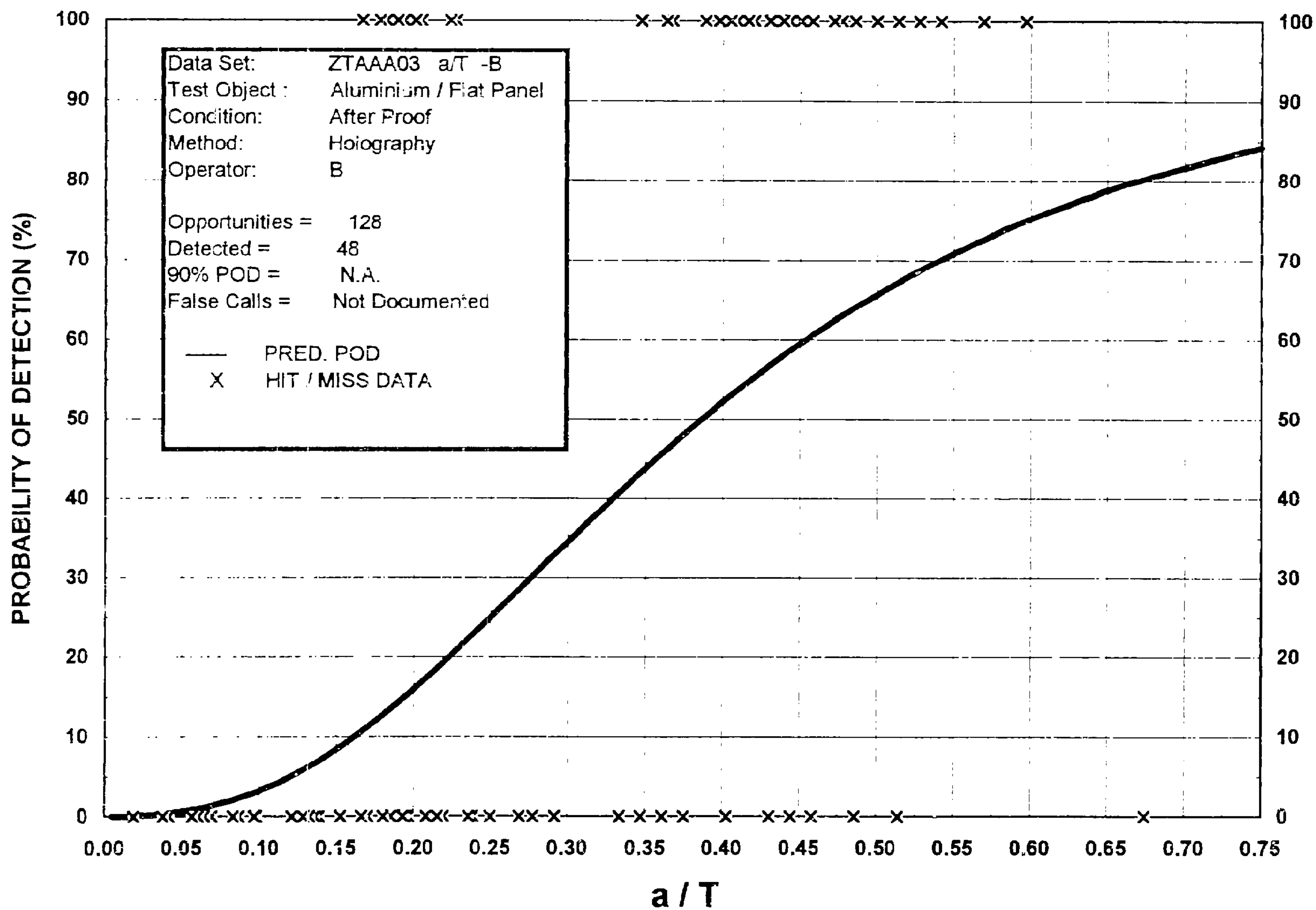
ZT 01 (1) B, HOLOGRAPHIC INTERFEROMETRY
6/95

ZTAAA03D-B
ALUMINUM - FLAT PLATE
OPERATOR B



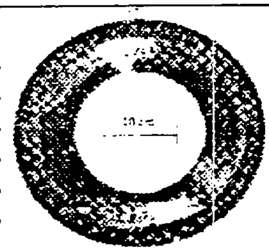
ZT 01 (1) C, HOLOGRAPHIC INTERFEROMETRY
CRACK DEPTH TO THICKNESS RATIO
6/95

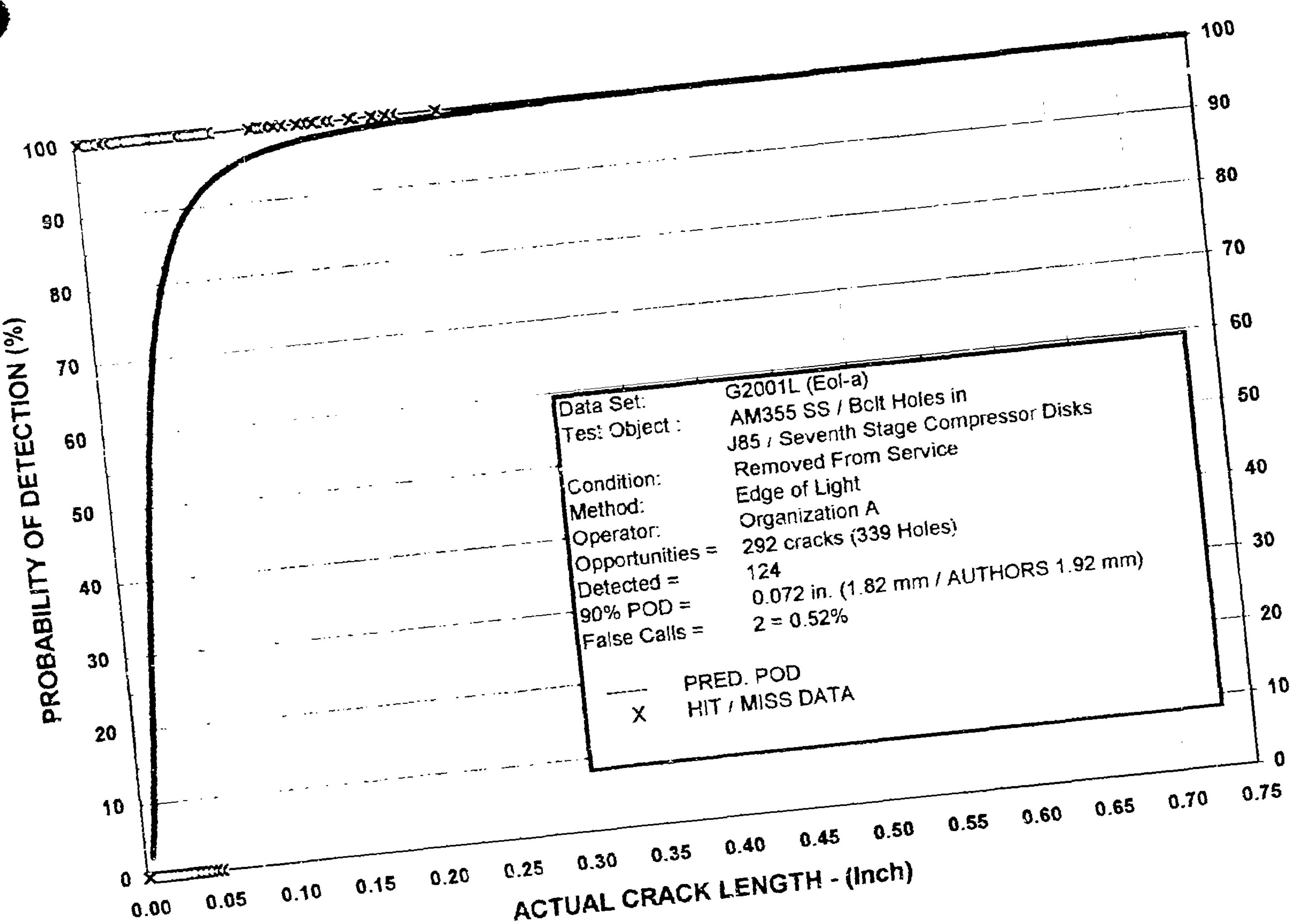
ZTAAA03 a / T -A
ALUMINUM - FLAT PLATE
OPERATOR A



ZT 01 (1) C, HOLOGRAPHIC INTERFEROMETRY
CRACK DEPTH TO THICKNESS RATIO
6/95

ZTAAA03 a / T -B
ALUMINUM - FLAT PLATE
OPERATOR B

G2000(7)L	DATA SET DESCRIPTION
METHOD:	Edge of Light Inspection
TEST OBJECT TYPE:	Bolt holes in J85 / Seventh stage compressor disks; 0.188 in. (4.8 mm) diameter
NDE PROCEDURE:	"Edge of Light" (Patent Pending)
ARTIFACT TYPE:	Service induced fatigue cracks
ARTIFACT SHAPE:	ASPECT RATIO - 0.1 TO O.5 (a/c) --- DEPTH TO THICKNESS - 0.2 TO 0.5 (a/t)
ARTIFACT VERIFICATION:	Destructive analysis and measurement
MATERIAL:	Precipitation hardened martensitic (AMS 355) stainless steel
TEST OBJECT THICKNESS:	0.075 inch (1.9 mm) nominal
TEST OBJECT CONDITION:	Removed from service
SURFACE FINISH:	Condition as removed from service - original surface rough polished
APPLICATION:	Automated Scan
DATA SET IDENTIFIERS:	G2001L
TYPE OF DATA:	Hit / Miss with ratings of indication magnitude
TEST OPPORTUNITIES:	381 Holes / 320 cracks
DETECTED:	G2001L - 124
FALSE CALLS:	G2001L - 2
REFERENCE:	LTR-ST-2055, D.S. Forsyth and A. Fahr, **The Sensitivity and Reliability of NDI Techniques for Gas Turbine Components Inspection and Life Prediction**,
DATE:	August, 1996.
WORK SPONSOR:	Department of National Defence. DAS Eng 6-2.
PERFORMING ORGANIZATION:	Institute for Aerospace Research. National Research Council Canada
NOTES:	The maximum likelihood method of curve fitting used in this databook differs slightly from the algorithm used by the authors. The authors calculated values are shown for reference.
	Maximum differences are shown for those data sets with the greatest variance. The authors noted difficulties fitting such data to the model.
	90% POD ORG A: 0.072 in. (1.82 mm / Authors - 1.92 mm)



G2001L Service Induced Cracks
ORGANIZATION A

G2000(7) EDGE OF LIGHT INSPECTION OF BOLT HOLES

9/96 - G2001L

NTIAC
NONDESTRUCTIVE TESTING INFORMATION ANALYSIS CENTER
415 Crystal Creek Drive • Austin, Texas 78746
Phone #(512) 263-2106 • FAX #(512) 263-3530 • e-mail: ntiac@access.texas.gov

June 2, 1998

Office of the Director of Defense
Research and Engineering
Advanced Technology
Room 3D1089
3080 Defense Pentagon
Washington, DC 20301-3080

Attn: Dr. L. Sloter, Staff Specialist for Materials and Structures

Subject: Submission of Final Data Book as a Deliverable under CDRL A009, Contract SPO700-97-D-4003

Dear Dr. Sloter:

In conformance with Contract Data Requirements List Item A009, enclosed are two copies of the *Nondestructive Evaluation (NDE) Capabilities Data Book, Third Edition,* NTIAC: DB-97-02 submitted as a deliverable under NTIAC Contract SPO700-97-D-4003. Approval of this deliverable was received in your letter of May 26, 1998. Enclosed are both a hard copy of the Data Book in a three ring binder format and an electronic version on a CD. Additional copies have been distributed in conformance with CDRL A009.

Sincerely,

George A. Matzkanin

George A. Matzkanin, Director
NTIAC

cc: DTIC-AI (Elaine Stevens/Ron Hale; w/enclosure)
DTIC-OCC (w/enclosure)
DSCC/PLI (Barbara Niles; w/o enclosure)
Monte Fellingham, TRI/Austin; (w/o enclosure)